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PRELIMINARY MISSION PROFILE FOR APOLLO APPLICATIONS MISSION AAP-1/AAP-2 REVISION I

By Mission Analysis Branch and
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MISSION PLANNING AND ANALYSIS DIVISION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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CONTENTS

ILLUSTRATIONS

TABLES

NOMENCLATURE

AAP	Apollo Applications Program
AS	Apollo Saturn
$C_{D_{TRIM}}$	Trim Drag Coefficient
$C_{L_{TRIM}}$	Trim Lift Coefficient
CM	Command Module
CSM	Command Service Module
EVA	Extravehicular Activity
GMT	Greenwich Mean Time
IGM	Iterative Guidance Mode
IMU	Inertial Measurement Unit
IU	Instrumentation Unit
IVA	Intravehicular Activity
L/D_{TRIM}	Trim Lift-over-drag Ratio
LES	Launch Escape System
LM	Lunar Module
M	Mach Number
M. R.	Mixture Ratio
MSC	Manned Spacecraft Center
MSFC	Marshall Space Flight Center
MSFN	Manned Space Flight Network
NASA	National Aeronautics and Space Administration
N_{C1}	Spacecraft Phase Adjustment Maneuver
N_{CC}	Spacecraft Corrective Combination Maneuver
N_{SR}	Spacecraft Coelliptic Maneuver

NOMENCLATURE (Continued)

OWS	Orbital Workshop
PM	Payload Module
PMP	Preliminary Mission Profile
RCS	Reaction Control System
S	Saturn
S-IVB	Second Stage of Uprated Saturn I Launch Vehicle
SLA	Spacecraft LM Adapter
SM	Service Module
SPS	Service Propulsion System
TPI	Terminal Phase Initiation
TPF	Terminal Phase Finalization
UHF	Ultra High Frequency
VHF	Very High Frequency
α_{TRIM}	Trim Angle of Attack
deg	Degree
er	Earth Equatorial Radius
ft	Foot
g.e.t.	Ground Elapsed Time
hr	Hour
km	Kilometer
lb	Pound
min	Minute
nd	Non-dimensional
n mi	Nautical Mile
rad	Radian
sec	Second

1. INTRODUCTION AND SUMMARY

1.1 MISSION PROFILE SUMMARY

The revised preliminary mission planning trajectory described in this document is designed for a manned-configured spacecraft on Apollo Applications Mission AAP-1/AAP-2. This will be a dual launch mission with an unmanned vehicle (AAP-2) being launched approximately 1 day after the launch of a manned-configured spacecraft (AAP-1).

The basic purposes of Mission AAP-1/AAP-2 include the following:

a) Demonstration of the capability of the orbital workshop (an S-IVB stage fitted with an airlock) when docked to a command service module (CSM) to provide a habitable environment for astronaut activity to complete a mission of up to 28 days from the time of initial launch of AAP-1

b) Provision of an orbital workshop which can be stored in orbit for a period up to 1 year and will be capable of reactivation and rehabitation for long duration missions anytime within that period when resupplied

c) Demonstration of the feasibility of a long duration (up to 28 days) manned spaceflight mission by use of expendables carried external to the CSM

d) Medical, technological, engineering, scientific, and applications experiments conducted in earth orbit that contribute to future space applications

For simulation purposes, the AAP-1 launch is assumed to occur on 15 January 1969, at 21:00 hours Greenwich Mean Time (GMT) (4:00 p.m. Eastern Standard Time) from Launch Complex 34 at Cape Kennedy, Florida. This late afternoon launch time was selected in order to insure daylight recovery of the AAP-1 CM at termination of the anticipated 28 day mission.* AAP-2 would be launched from Launch Complex 37B on 16 January 1969, 23 hours 24 minutes 15 seconds after the lift-off of AAP-1.

*It was assumed that this launch time, which satisfies this constraint in the PMP, would also satisfy the constraint in the revised PMP, but it does not (Section 1.2.5).

The mission profile has been divided into four periods of activity. These periods, and the corresponding significant mission events, are as follows:

a) First period of activities (00:00:00:00 to 00:23:24:15, g. e. t. in day:hour:minute:second)

   1) AAP-1 ascent to orbit inserting the S-IVB/CSM into a 81-by 110-nautical mile elliptical orbit

   2) CSM separation from the S-IVB; circularization of the CSM orbit at a 110-nautical mile altitude by use of the SPS at second apogee

   3) CSM coast until AAP-2 lift-off

b) Second period of activities (00:23:24:15 to 01:04:09:41, g. e. t.)

   1) AAP-2 ascent to orbit inserting the unmanned modified S-IVB/airlock orbital workshop into a 260- by 260-nautical mile circular orbit, which is immediately altered to a 257- by 270-nautical mile elliptical orbit due to passivation of the S-IVB

   2) CSM active rendezvous

   3) CSM docking with orbital workshop

   4) CSM/orbital workshop coast phase

c) Third period of activities (01:04:09:41 to 25:03:00:00, g. e. t.) orbital workshop experiments to 25th day.

d) Fourth period of activities (25:03:40:00 to 25:10:00:21.7, g. e. t.)

   1) CSM/orbital workshop separation

   2) CSM deorbit maneuver

   3) CM entry

1.2 MISSION PROFILE EVALUATION

The objective of this Revised Preliminary Mission Profile is to present a realistic sequence of mission events which attempts to satisfy the mission requirements and constraints as defined in Reference 1. Problem areas that were described in the Preliminary Mission Profile (Reference 2) and the analysis of these problems will be discussed in this section.

1.2.1 Launch Vehicle Performance

The Preliminary Data Specification (Reference 3) defines the total and component weights of the AAP-1 and AAP-2 vehicles (Table 1). The Lunar Mapping and Surveying System and its associated experiments have been deleted from the AAP-1/2 mission, reducing the total weight by 4000 pounds. However, provisions are made on the service module to accommodate an additional 2383 pounds of RCS propellant (Section 1.2.4). The result is a net weight decrease of 1617 pounds for AAP-1. This decrease is the only significant change to the AAP-1 vehicle. The only significant change to the AAP-2 vehicle is the addition of the eight solar array panels, the total weight of which is 2741 pounds. Hence, the net weight of the AAP-2 vehicle is increased by this amount. The new launch weights and payloads of both vehicles were compared with the launch vehicle payload capabilities of the Uprated Saturn I launch vehicle quoted by MSFC, and found to be compatible.

1.2.2 S-IVB Passivation

Another area that was considered critical concerned the effects of propulsive vents during the S-IVB passivation sequence on the rendezvous operation. The analysis of this problem resulted in the decision to passivate the S-IVB immediately after insertion and prior to the initiation of the rendezvous maneuvers. The propulsive venting is done with the S-IVB pitched up 72 degrees causing the insertion orbit to become slightly elliptic.

1.2.3 S-IVB Instrumentation Unit Lifetime

The operational lifetime of the S-IVB instrumentation unit as stated in the PMP remains unchanged at 7.5 hours. It is desired to have the CSM complete the docking maneuver with the orbital workshop while the workshop has an attitude control capability. However, the attitude control capability exists only while the instrumentation unit is operational.

Deletion of the Lunar Mapping and Survey System and its associated docking and extraction maneuvers with the CSM and docking with the multiple docking adaptor resulted in reducing the time of docking maneuver completion from 14.5 hours (PMP) to 4 hours following AAP-2 lift-off. This reduction in time insures the attitude control capability of the OWS during the CSM OWS docking maneuver.

1.2.4 Service Module RCS Propellant Deficit

The SPS propellant requirements for the AAP-1/2 mission are well below the maximum quantity that the Block II service module propellant tanks can accommodate. However, the SM RCS propellant requirements are far above the propellant storage capability. Because of the above, the service module propellant tankage system modification was necessary. This modification consists of removing a portion of the SPS tankage system and adding a supplementary RCS tankage system, increasing the RCS propellant quantity from 1200 pounds to 3583 pounds. This modification allows the RCS propellant requirements for the AAP-1/2 mission to be satisfied (Table 2).

1.2.5 Recovery Area Lighting Conditions

The preliminary mission profile designed for the AAP-1/2 mission results in unsatisfactory splashdown lighting conditions in the Western Atlantic recovery zone after the 25th day of the mission. The recovery area lighting constraint as stated in Reference 4 restricts splashdown to no earlier than 1 hour prior to sunrise and no later than 1 hour prior to sunset. This constraint insures daylight recovery operations. The AAP-1/2 mission presented in this document is terminated after 25 days and splashdown occurs 40 minutes prior to sunrise, (Figure 1), thus satisfying the stated constraint. For each succeeding deorbit opportunity, the time between splashdown and sunrise increases by approximately 36 minutes, thereby failing to satisfy the daylight recovery constraint. The assumed launch time for the AAP-1 vehicle is 21:00 hours (GMT) (4:00 p.m. Eastern Standard Time); therefore, the mission duration cannot be extended by a later launch time without violating the launch abort in daylight constraint, Reference 4. It can be concluded that a 28-day mission is incompatible with the stated launch and recovery lighting constraints; however, a 25-day mission does satisfy these constraints.

2. MISSION OBJECTIVES AND MISSION REQUIREMENTS

2.1 MISSION OBJECTIVES

The following mission objectives for AAP-1/2 were taken from the Preliminary Mission Requirements document for Missions AAP-1 through 4 (Reference 1). These objectives have not been published in an official document but are based on the latest information available and are presented for information purposes only.

2.1.1 Primary

a) Conduct long duration mission (up to 28 days) using a spent S-IVB stage (orbital workshop), an airlock, an MDA, and an Apollo CSM. The mission is intended to perform the following tasks:

   1) Evaluate effects of the long duration mission on CSM/S-IVB airlock systems and subsystems

   2) Evaluate space flight environmental effects on the crew and determine human task performance capability during the long duration mission

   3) Demonstrate hard-dock of the CSM to the MDA

   4) Demonstrate passivation of the spent S-IVB stage and activation of the workshop as a habitable space structure

   5) Verify the ability of mission ground support systems to support mission activities of extended duration

b) Leave assembly in orbit for reactivation and reuse up to 1 year later

2.1.2 Secondary

Conduct experiments in the areas of science, applications, biomedical, technology, and engineering

2.2 MISSION REQUIREMENTS

The following mission requirements for AAP-1/2 were taken from the Preliminary Mission Requirements document for Missions AAP-1 through 4.

(Reference 1). The mission requirements have not been published in an official document but are presented as they are presently defined.

a) AAP-1 will be launched from Complex 34 on a flight azimuth which results in an inclination that will provide compatible launch windows for AAP-2 launched 1 day later from Complex 37B. Provisions must also be considered to provide compatible launch windows for Mission AAP-3/AAP-4 up to 1 year later.

b) The initial orbit for AAP-2 must be of sufficient altitude to provide a minimum of 1-year lifetime (-2σ) considering random orbital stabilization for the first month of operation, gravity gradient stabilization during all storage modes, and sun referenced stabilization during the AAP-3/4 mission.

c) The CSM shall be hard docked during all attitude maneuvers, during crew transfer, and throughout periods when umbilicals are connected between the CSM and MDA/airlock.

d) The S-IVB passivation will be accomplished automatically insofar as possible. A manual backup capability is required. Venting of LH_2 and LOX on the S-IVB will be non-propulsive (maximum 2 feet per second ΔV) following the initial vent immediately after orbital insertion and insertion until after docking of the CSM to the MDA.

e) The S-IVB/IU for AAP-2 shall provide attitude control for CSM docking to the MDA. If the AAP-S-IVB/IU 7 1/2-hour attitude control lifetime is insufficient for the mission, either an increased lifetime for the present system or the use of the auxiliary attitude stabilization system will be required.

f) Ground monitoring of the AAP-1/AAP-2 is required throughout the mission. Monitoring during the latter stage should be of similar magnitude to that of the early phase of the mission.

g) The AAP-1/AAP-2 mission duration shall be planned for up to 28 days referenced from the AAP-1 launch to splashdown of the AAP-1 CM.

h) A backup deorbit capability for the CSM is required.

i) There will be no maneuvering of the orbital assembly using the CSM-SPS.

3. SUMMARY OF INPUT DATA

The data presented in this section were obtained from References 2, 3, 5, 6, 7, and 8 and from technical coordination meetings of MSC and TRW personnel. Included in this section are those MSFN and spacecraft specifications that form the basis for the preliminary mission planning of the Apollo Applications Mission AAP-1/AAP-2.

3.1 SATURN LAUNCH VEHICLE

The Uprated Saturn I launch vehicle which will be used to insert both the AAP-1 and AAP-2 payloads into initial earth orbit is comprised of the S-IB and S-IVB stages. The ascent-to-orbit trajectories upon which the preliminary mission planning is based were generated from Saturn IB launch vehicle configurations presented in the AS-207 and the AS-208 launch vehicle reference trajectories (References 5 and 6). These launch vehicle configurations are representative of those to be used for AAP-1 and AAP-2, respectively.

3.2 AAP-1 and AAP-2 SPACECRAFT

The AAP-1 spacecraft consists of a Block II Apollo CSM with modifications and an operational spacecraft LM adapter (SLA). The unmanned AAP-2 spacecraft, or orbital workshop, consists of a spent modified S-IVB stage, a SLA, the airlock (carried in the SLA on the LM attach points), a MDA and a nosecone. The AAP-2 vehicle and the combined AAP-1/AAP-2 configuration are illustrated in Figures 2, 3, and 4. The spacecraft data and specifications required to support this preliminary mission planning are presented in the following subsections.

3.2.1 Weight Characteristics

The spacecraft weight characteristics were obtained from Reference 3. These data are summarized in Table 1.

3.2.2 Performance Characteristics

The performance characteristics of the SM-RCS were obtained from Reference 2. In this preliminary mission planning, the RCS was used primarily for translational maneuvers. Such maneuvers are assumed to require four thrusters; the performance characteristics of a single RCS thruster are shown in Table 3. The performance characteristics of the SPS were obtained from Reference 3 and are summarized in Table 4.

3.2.3 Reentry Aerodynamic Characteristics

The pertinent aerodynamic characteristics during reentry of AAP-1 were obtained from Reference 3 and are presented in Table 5.

3.3 MSFN STATIONS

The MSFN stations to support Apollo Applications Mission AAP-1/AAP-2 have not been officially identified. For trajectory simulation purposes, the MSFN stations to be used for Apollo Mission AS-503 (References 7 and 8)were assumed available except that the ship positions have been altered. The locations and capabilities of these stations are summarized in Table 6. MSFN station coordinates are referenced to the Fischer ellipsoid.

4. NOMINAL MISSION ANALYSIS AND DESCRIPTION

The description of Apollo Applications Mission AAP-1/2 resulting from the trajectory analysis performed during the preliminary mission planning is presented in this section.

4.1 FIRST PERIOD OF ACTIVITIES

The first period of activities for Apollo Applications Mission AAP-1/AAP-2 is initiated at 21:00 hours GMT (4:00 p.m. EST) on an assumed date, 15 January 1969, with the lift-off of AAP-1 from launch complex 34 at Cape Kennedy along a flight azimuth of 83 degrees. The S-IVB/CSM is inserted into an 81- by 110-nautical mile orbit approximately 595 seconds after lift-off.

At approximately 2 hours 22 minutes ground elapsed time (g.e.t.), an SPS maneuver to circularize the orbit at 110 nautical miles is performed at second apogee, immediately prior to acquisition by the Carnarvon tracking station.

The 110-nautical mile circular orbit provides a launch window the following day for a near inplane launch of the orbital workshop (OWS). A near inplane launch minimizes booster yaw steering and performance loss. This orbit also provides recurring launch opportunities for successive days (see Figure 5) with a similarly small yaw steering requirement. (Two launch opportunities a day for at least 4 days are desirable.)

Trajectory data pertinent to the first period of activities are presented in graphical and tabular form at the end of the text. Figure 6 shows the timeline from AAP-1 lift-off through the circularization maneuver as a function of g.e.t. Table 7 lists the periods of daylight and darkness up to the end of the rendezvous sequence. The ground tracks for the first 5 orbit revolutions are shown in Figure 7. MSFN acquisition and loss times for the CSM's first 20 revolutions are given in Table 8.

4.2 SECOND PERIOD OF ACTIVITIES

With the CSM coasting in the 110-nautical mile circular orbit, the second period of activities is initiated with the lift-off of AAP-2 from launch complex 37B on 16 January 1969, 20 hours, 24 minutes and 15 seconds GMT (approximately 23 hours 24 minutes g.e.t.) along an azimuth of 83.3 degrees.

Insertion of the OWS (AAP-2) into a 260-nautical mile circular orbit occurs approximately 588 seconds after lift-off and precedes the CSM by a 29.4-degree central angle. The S-IVB passivation sequence is initiated about 1 minute after OWS insertion, and consists of dumping the oxidizer and hydrogen fuel through the J-2 engine nozzle which produces an inplane impulse of approximately 45 feet per second. In order to minimize the required radial velocity component for the CSM at the coelliptic maneuver point, the OWS is pitched up 72 degrees from the local horizontal at the time of this passivation impulse. This results in an OWS orbit of 257 by 270 nautical miles with perigee shifted about 60 degrees west of the insertion point, thereby coinciding inertially with the desired maneuver line.

One hour, 23 minutes, and 6 seconds after OWS insertion, the CSM performs a phasing (N_{C1}) maneuver to initiate the rendezvous sequence. This maneuver at approximately 1 day 0 hour 56 minutes g.e.t. consists of a 17-second SM-RCS four jet ullage phase followed by a 10.4-second SPS thrusting period. The ΔV obtained from this burn is 242.8 feet per second and the resulting CSM orbit is 109 by 248 nautical miles. MSFN coverage is provided by the Mercury tracking ship.

About 45 minutes after the N_{C1} maneuver, the CSM will perform a corrective combination (N_{CC}) maneuver. This maneuver is initiated at apogee of the orbit, (1 day 1 hour and 2 minutes g.e.t.), with a 17-second ullage maneuver followed by a 10.0-second SPS burn yielding a ΔV of 239.5 feet per second. The resultant CSM orbit is 247 by 248 nautical miles. The major purpose of the maneuver is to adjust the perigee height; however, any phase or planar dispersions, or both, will also be corrected at this point. The MSFN coverage will be provided by the Redstone tracking ship.

The coelliptical maneuver (N_{SR}) will be performed 45 minutes after the N_{C1} maneuver at approximately 1 day 2 hours 28 minutes g. e. t. This SM-RCS maneuver (ΔV = 21.1 feet per second) is initiated at apogee and is designed to place the CSM on an ellipse that is coelliptic (the orbits' apsides aligned) with that of the OWS. This coelliptic condition maintains a near-constant height differential of 10 nautical miles between the two orbits until after the TPI maneuver. The nominal N_{SR} maneuver was planned as an RCS burn for convenience so that the CSM crew can quickly resume optical tracking of the target; i. e., one man can remain in the navigation bay, which is not possible if the SPS is utilized. MSFN coverage is provided by the Hawaii tracking station.

Approximately 30 minutes following the N_{SR} maneuver, the terminal phase initiation (TPI) maneuver is performed at approximately 1 day 2 hours 58 minutes g. e. t. TPI is a 44.3-second RCS burn of 19.7-feet per second ΔV, which places the CSM on a trajectory that will intercept the OWS after 140 degrees of central angle travel. MSFN coverage during this burn will be provided by the Redstone tracking ship.

The terminal phase finalization (TPF) maneuver is initiated following a coast of 36 minutes 36 seconds after TPI at approximately 1 day 3 hours 35 minutes g. e. t., about 4 hours 11 minutes after OWS lift-off. This theoretical maneuver to rendezvous consists of 52.5 seconds of RCS burn, providing a ΔV of 23.3 feet per second.

Post-rendezvous stationkeeping and docking with the OWS will be covered by United States MSFN stations.

The trajectory data pertinent to the second period of activities are presented at the end of the text. Figure 8 presents a timeline of the major events of this second period of activities. Figure 9 shows the relative motion of AAP-1 and AAP-2 during the rendezvous. Figure 10 depicts the relative range and range rate between AAP-1 and AAP-2 as a function of g. e. t. The rendezvous orbit geometry of AAP-1/AAP-2 is shown in Figure 11. Tables 9 and 10 show the discrete events and the state vectors of the first two periods of activity, respectively. The ground tracks for revolutions 16 through 20 are shown in Figure 12. As noted previously, the periods of daylight and darkness and the MSFN acquisition and loss times for the first two periods are presented in Tables 7 and 8.

4.3 THIRD PERIOD OF ACTIVITIES

The third period of activities will be devoted to performing experiments. Following the rendezvous and docking of the CSM with the orbital workshop, the vehicles coast in an elliptical orbit at an altitude of approximately 257 by 270 nautical miles for about 24.5 days. This period will be devoted to demonstrating the suitability of the spent S-IVB stage as a habitable space structure in the orbital workshop configuration and to evaluating the performance of orbital workshop crew operations for a mission duration up to 28 days. A preliminary description of the associated experiments is provided in Reference 1.

4.4 FOURTH PERIOD OF ACTIVITIES

Following the 24.5-day coast period and approximately 3 hours prior to the deorbit maneuver, the CSM separates from the orbital workshop. Approximately 10 minutes prior to the deorbit burn, the CSM is maneuvered into the proper retrograde attitude (pitched down 53.2 degrees from the local horizontal in the negative velocity vector direction). This attitude is 31.7 degrees below the line-of-sight vector to the horizon.

An SPS deorbit has been used in this preliminary mission plan. At a g.e.t. of approximately 25 days 11 hours 18 minutes, an SM-RCS ullage maneuver lasting 17 seconds is initiated. One second prior to completion of the ullage maneuver, the SPS is ignited and burns for 25.95 seconds. This SPS burn produces a ΔV of 709.2 feet per second and places the CSM on an ellipse that intersects the earth's atmosphere; a resultant inertial flight-path angle of 1.89 degrees below the local horizontal is achieved at the entry interface altitude of 400,000 feet. The deorbit sequence is designed so that splashdown occurs in the Western Atlantic primary recovery area at 60° West longitude to insure that debris from the SM does not fall on the mainland. The deorbit maneuver occurs in darkness. The deorbit maneuver must be initiated east of Hawaii to insure CM splashdown in the Western Atlantic recovery area. This precludes use of the Hawaii tracking facilities and necessitates using a tracking ship for MSFN coverage of the deorbit maneuver.

A coast of 22.8 minutes follows the deorbit maneuver until the entry interface altitude is reached. Approximately 5 minutes prior to reaching this altitude, the SM is jettisoned, and the CM maneuvers to the desired entry orientation. The CM is in a retrograde attitude and pitched up approximately 21 degrees for entry.

At a g.e.t. of 25 days 12 hours 49 minutes 44 seconds, the CM reaches the atmospheric entry altitude of 400,000 feet with an inertial velocity magnitude and a flight-path angle of 25,983.3 feet per second and 1.89 degrees below the local horizontal, respectively.

The entry trajectory was established without the use of guidance. An average bank angle of 55 degrees was used to simulate the aerodynamics during the entry and, according to previous entry studies (Reference 9), results in CM splashdown near the center of the landing footprint.

Drogue chute deployment begins when the CM reaches an altitude of 23,500 feet. This event occurs 7 minutes 43 seconds after reaching the entry interface altitude.

Main chute deployment begins when the CM reaches an altitude of 10,200 feet. This event occurs 25 seconds after the drogue chute deployment.

The mission is terminated at a g.e.t. of 25 days 13 hours 0 minutes 21.7 seconds with CM splashdown at 21.2° North latitude and 59.5° West longitude.

The total earth relative range from entry interface altitude to splashdown is approximately 1295 nautical miles.

Trajectory data pertinent to this period of activities are presented in graphical and tabular form at the end of the text. Figure 1 depicts the major events from deorbit to splashdown, including the periods of daylight and darkness, and the available MSFN coverage, as a function of AAP-1

g. e. t. Figure 13 is an earth ground track of AAP-1 showing the CM entry and splashdown. Figure 14 is a longitude history of spacecraft inertial flight-path angle, altitude, and earth relative velocity from deorbit impulse to splashdown. Table 11 is a discrete events summary for the fourth period of activities.

4.5 SPS AND RCS PROPELLANT BUDGET

Table 2 represents a preliminary SPS and RCS propellant budget for the AAP-1/AAP-2 mission. Estimates of propellant usage for those events not generated in the trajectory simulation have been included to present a complete evaluation of the SPS-RCS propellant requirements. It can be seen that the propellant available is sufficient to support the AAP-1/2 mission.

Table 1a. AAP-1 Payload Weight Characteristics

Item	Predicted Weight (lb)
Command Module	12512
Service Module (Less Propellant)	9473
SPS Propellant	4398
RCS Propellant	3583
Spacecraft LM Adapter (SLA)	3947
Launch Escape System (LES)	8650
Total Payload Weight At Launch	42563
LES Jettison	-8650
Total Payload Weight Inserted Into Orbit	33913
SLA Jettison (With S-IVB)	-3947
Total Spacecraft Weight In Orbit	29966

Note: Payload is defined as all components above the instrumentation unit.

Table 1b. AAP-2 Payload Weight Characteristics

Item	Predicted Weight (lb)
Airlock	14300
Multiple Docking Adapter (MDA) With Experiments	6027
S-IVB Modifications	3200
S-IVB Solar Arrays	2741
Spacecraft LM Adapter (SLA) With Modifications	4100
Nose Cone	1000
Total Payload Weight At Launch	31368
Nose Cone Jettison	-1000
Total Payload Weight Inserted Into Orbit	30368
Inert S-IVB Stage	21946
Instrumentation Unit (IU)	4300
Total AAP-2 Vehicle Weight In Orbit	56614

Note: Payload is defined as all components above the Instrumentation Unit plus weight of structural modifications to the S-IVB (including solar arrays) as required for the orbital workshop.

Table 2. AAP-1 SPS and RCS Propellant Budget

Event	Configuration Weight (lb)	ΔV (ft/sec) SPS	ΔV (ft/sec) RCS	Propellant (lb) SPS	Propellant (lb) RCS	Remarks
Insertion	29966.0					Insertion Orbit 81/110 n mi
CSM-S-IVB Separation	29950.3				15.7	
IMU Alignment and Orientation for SPS Burn	29945.1				5.2	
Ullage	29923.3		7.3		21.8	
Circularization Burn	29790.3	53.1		2.5 133.0		109.5/110 n mi
IMU Alignment and Orientation	29785.1				5.2	
Navigation Sighting	29782.7				2.4	
Ullage	29760.9		7.4		21.8	
N_{cl} Maneuver	29053.9	242.8		2.9 707.0		109/248 n mi
IMU Alignment and Orientation	29048.7				5.2	
Ullage	29026.9		7.6		21.8	
N_{CC} Maneuver	28351.9	239.5		2.8 675.0		247/248 n mi
Orientation	28350.1				1.8	
N_{SR} Maneuver	28265.7		21.2		84.4	247/260 n mi
Orientation	28263.9				1.8	
TPI Maneuver	28185.9		19.7		78.0	251/266 n mi

Table 2. AAP-1 SPS and RCS Propellant Budget (Continued)

Event	Configuration Weight (lb)	ΔV(ft/sec) SPS	ΔV(ft/sec) RCS	Propellant (lb) SPS	Propellant (lb) RCS	Remarks
Midcourse Maneuvers and Braking (Includes TPF)	27635.9		23.3		550.0	257/270 n mi
Station Keeping and Docking with OWS	27520.9				115.0	50 lb for Station Keeping; 65 lb for Docking
Attitude Maneuvers and Holds, RCS Trim, Shutdown Transients	27495.9				25.0	6 lb/RCS Trim 4 lb/Attitude Maneuver 1 lb/Transients
Attitude Control of OWS	27370.9				125.0	Estimate 5 lb/day
CSM Undocking	27365.9				5.0	
IMU Alignment and Orientation	27360.7				5.2	
Navigation Sighting	27358.3				2.4	
Ullage	27336.5		3.1 6		21.8	
Deorbit Maneuver	25663.0	709.2	2.3	1673.5		
SM Spin-up and Jettison	25628.0				35.0	
				3188.5	1149.5	
Nominal Propellant Estimate						
Terminal Phase Dispersions						
Rendezvous					150.0	
Docking					90.0	

Table 2. AAP-1 SPS and RCS Propellant Budget (Continued)

Event	Configuration Weight (lb)	ΔV(ft/sec)		Propellant (lb)		Remarks
		SPS	RCS	SPS	RCS	
Operational Reserve					32.0	
RCS Propellant Required for Backup Deorbit					1100.0	
Total Propellant Estimate				3188.5	2521.5	
Total RCS and SPS Propellant Available				4398.0	3583.0	

Table 3. RCS Thruster Performance Characteristics

Thrust (lb)	Flow Rate (lb/sec)
99.7	0.36

Note: The above are nominal single engine values for steady state operation (vacuum).

Table 4. SPS Performance Characteristics

Thrust	20,290 lb ±1.5 percent
Specific Impulse	313.5 ±2 sec
Oxidizer Flow Rate	39.72 lb/sec ±3 percent
Fuel Flow Rate	24.66 lb/sec ±3 percent
Mixture Ratio	1.6/1 ±3 percent

Note: The above are nominal values, for steady state operation (vacuum).

Table 5a. Command Module Reentry Trim Aerodynamic Coefficients

M	α_{trim} (deg)	$C_{L_{trim}}$	$C_{D_{trim}}$	L/D_{trim}
0.2	169.7	0.267	0.816	0.327
0.4	165.4	0.281	0.845	0.332
0.7	161.9	0.292	0.964	0.303
0.9	158.7	0.361	1.037	0.348
1.1	152.5	0.530	1.141	0.464
1.2	152.3	0.524	1.124	0.466
1.35	150.7	0.612	1.235	0.495
1.65	150.4	0.582	1.226	0.475
2.0	150.2	0.553	1.211	0.457
2.4	150.6	0.530	1.190	0.445
3.0	151.5	0.500	1.161	0.431
4.0	153.7	0.464	1.167	0.398
Hypersonic	157.4	0.425	1.236	0.340

Note: Reference length of CM = 154.0 in.
Reference area of CM = 129.5 ft^2

Table 5b. Command Module Normal Parachute Descent Events and Aerodynamics

Altitude (ft)	Time (sec)	C_DS (per chute) (ft^2)	Event
23,500	+ 0.0	0	High-altitude baroswitch closed (actuate ELS)
	+ 2.0	0	Deploy drogue chutes
	+ 2.8	40	Drogue chute reefed inflation (39 percent reefing)
	+ 10.7	40	Drogue chute disreef
	+ 11.0	68	Drogue chutes full open (62 percent reefing)
10,200	+ 0.0	0	Low-altitude baroswitch closed; pilot mortar fire
	+ 2.1	0	Main chute line stretch
	+ 3.5	300	Reefed inflation (9.5 percent reefing)
	+ 10.0	300	Begin main chute disreef
	+ 13.0	4000	Mains full open

Note: Drogue parachute reference diameter, D_o = 13.7 ft, 25-degree conical ribbon. Main parachute reference diameter, D_o = 83.5 ft; fifth ring is 75 percent removed.

Table 6. MSFN Stations and Capabilities

Station	Call Letters	Latitude (Geodetic)	Longitude	Unified S-band High Speed	Unified S-band Low Speed	C-band Tracking High Speed	C-band Tracking Low Speed	VHF Telemetry	VHF Voice	UHF Command
Merritt Island	MIL	28.508272	-80.693417	Yes	Yes					
Merritt Island	MLA	28.424861	-80.664404			Yes	Yes	Yes	Yes	Yes
Grand Bahama	GBM	26.632857	-78.237664	Yes	Yes					
Grand Bahama	GBI	26.636350	-78.267709			Yes	Yes	Yes	Yes	Yes
Bermuda	BDA	32.351286	-64.658334	Yes	Yes					
Bermuda	BDA	32.348102	-64.653800			Yes	Yes	Yes	Yes	Yes
Antigua	ANG	17.016916	-61.752849	Yes	Yes					
Antigua	ANT	17.144030	-61.792900			Yes	Yes	Yes	Yes	Yes
Grand Canary	CYI	27.764536	-15.634814	No	Yes					
Grand Canary	CYI	27.763205	-15.634814			No	Yes	Yes	Yes	Yes
Ascension	ACN	-7.955055	-14.327578	Yes	Yes					
Ascension	ASC	-7.972761	-14.401695			Yes	Yes	Yes	Yes	No
Madrid	MAD	40.455358	-4.167395	Yes	Yes	No	No,	No	No	No
Pretoria	PRE	-25.943733	28.358488	No	No	Yes	Yes	Record	No	No
Tananarive	TAN	-19.018055	47.304444	No	No			Record	Relay	No
Carnarvon	CRO	-24.907591	113.724247	Yes	Yes					
Carnarvon	CRO	-24.897402	113.716077			Yes	Yes	Yes	Yes	Yes
Guam	GWM	13.309244	114.734413	Yes	Yes	No	No	Yes	Yes	No
Canberra	CNB	-35.584738	148.976577	Yes	Yes	No	No	No	No	No
Hawaii	HAW	22.124897	-159.664989	No	Yes					
Hawaii	HAW	22.122091	-159.665384			Yes	Yes	Yes	Yes	Yes
Point Arguello	CAL	34.582902	-120.561150	No	No	Yes	Yes	No	Relay	No
Goldstone	GDS	35.341694	-116.873289	Yes	Yes	No	No	No	No	No
Guaymas	CYM	27.963205	-110.720850	Yes	Yes	No	No	Yes	Yes	No
White Sands	WHS	32.358222	-106.369564	No	No	Yes	Yes	No	No	No

Table 6. MSFN Stations and Capabilities (Continued)

Station	Call Letters	Latitude (Geodetic)	Longitude	Unified S-band High Speed	Unified S-band Low Speed	C-band Tracking High Speed	C-band Tracking Low Speed	VHF Telemetry	VHF Voice	UHF Command
Texas	TEX	27.653750	-97.378470	Yes	Yes	No	No	Yes	Yes	Yes
Vanguard	VAN	21.800000	-44.000000	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Redstone	RED	-25.000000	40.000000	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mercury	MER	23.000000	-138.000000	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Deorbit Ship	DOS	5.000000	-175.000000	Yes	Yes	Yes	Yes	Record	Yes	No

Notes: (1) C-band sites listed separately.
(2) Minus sign indicates south latitude or west longitude.

Table 7. Daylight and Darkness/ First and Second Period of Activities

LIGHTING FOR AAP 1

REV NO.	LONGITUDE	LATITUDE	GMT D,H,M,S	GET H,M,S	
1	-42.1	25.7	0 21 14 33	0 14 33	SUNSET
1	94.4	-28.8	0 21 51 3	0 51 3	SUNRISE
2	-63.8	25.5	0 22 42 33	1 42 33	SUNSET
2	72.8	-28.8	0 23 19 3	2 19 3	SUNRISE
2	-82.3	24.5	1 0 11 39	3 11 39	SUNSET
3	51.4	-28.8	1 0 47 39	3 47 39	SUNRISE
3	-104.2	24.3	1 1 40 9	4 40 9	SUNSET
4	29.6	-28.8	1 2 16 9	5 16 9	SUNRISE
4	-128.1	24.5	1 3 8 9	6 8 9	SUNSET
5	5.6	-28.8	1 3 44 9	6 44 9	SUNRISE
5	-150.0	24.4	1 4 36 39	7 36 39	SUNSET
6	-16.2	-28.8	1 5 12 39	8 12 39	SUNRISE
6	-171.8	24.2	1 6 5 9	9 5 9	SUNSET
7	-38.0	-28.8	1 6 41 9	9 41 9	SUNRISE
7	166.0	24.0	1 7 33 39	10 33 39	SUNSET
8	-57.7	-28.9	1 8 9 39	11 9 39	SUNRISE
8	144.5	23.8	1 9 2 9	12 2 9	SUNSET
8	-31.5	-28.9	1 9 38 9	12 38 9	SUNRISE
9	122.7	23.5	1 10 30 39	13 30 39	SUNSET
9	-103.7	-28.9	1 11 6 39	14 6 39	SUNRISE
10	100.9	23.3	1 11 59 9	14 59 9	SUNSET
10	-125.0	-28.3	1 12 35 9	15 35 9	SUNRISE
11	79.0	23.0	1 13 27 39	16 27 39	SUNSET
12	-148.9	-28.9	1 14 3 9	17 3 9	SUNRISE
12	57.2	22.8	1 14 56 9	17 56 9	SUNSET
12	-170.6	-28.8	1 15 31 39	18 31 39	SUNRISE
13	35.5	23.1	1 16 24 9	19 24 9	SUNSET
13	167.7	-28.8	1 17 0 9	20 0 9	SUNRISE
14	11.7	22.9	1 17 52 39	20 52 39	SUNSET
14	146.0	-28.8	1 18 28 39	21 28 39	SUNRISE
15	-10.1	22.6	1 19 21 9	22 21 9	SUNSET
15	124.3	-28.8	1 19 57 9	22 57 9	SUNRISE
16	-31.9	22.3	1 20 49 39	23 49 39	SUNSET
16	100.5	-28.8	1 21 25 9	24 25 9	SUNRISE
17	-49.6	20.6	1 22 19 17	25 19 17	SUNSET
17	70.5	-28.8	1 22 53 46	25 53 46	SUNRISE
18	-68.5	18.6	1 23 54 4	26 54 4	SUNSET
18	44.4	-28.7	2 0 26 56	27 26 56	SUNRISE
18	-92.4	18.6	2 1 28 6	28 28 6	SUNSET
19	20.6	-28.7	2 2 1 6	29 1 6	SUNRISE
19	-115.1	18.0	2 3 2 36	30 2 36	SUNSET
20	-1.9	-28.8	2 3 35 36	30 35 36	SUNRISE
20	-139.6	18.2	2 4 36 36	31 36 36	SUNSET

Table 8. AAP-1 (CSM) MSFN Coverage (5-degree Minimum Elevation)

STATION NAME	STATION EQUIP	REV NO.	ACQUISITION D	ACQUISITION H	ACQUISITION M	ACQUISITION S	LOSS D	LOSS H	LOSS M	LOSS S	DURATION M	DURATION S	ACQ GMT D	ACQ GMT H	ACQ GMT M	ACQ GMT S	MAX ELEV DEGREES	ACQ RANGE N. MILES	MIN RANGE N. MILES
BDA	SCTUV	1	0	0	7	23	0	0	11	16	3	53	0	21	7	23	19.8	513.	222.
VAN	USBC	1	0	0	12	33	0	0	16	12	3	38	0	21	12	33	15.4	505.	268.
TAN	V	1	0	0	37	14	0	0	42	9	4	54	0	21	37	14	49.6	584.	131.
CRO	USBCV	1	0	0	53	5	0	0	58	4	4	59	0	21	53	5	27.6	625.	224.
CTN	V	1	0	1	12	51	0	1	16	53	4	1	0	22	12	51	15.3	575.	310.
MER	USBC	1	0	1	23	20	0	1	27	33	4	12	0	22	23	20	25.9	541.	189.
GYM	S T V	1	0	1	29	42	0	1	33	59	4	16	0	22	29	42	74.6	519.	85.
WHS	C	1	0	1	31	7	0	1	34	49	3	42	0	22	31	7	16.0	516.	264.
TEX	S TUV	1	0	1	32	45	0	1	36	57	4	11	0	22	32	45	46.4	512.	111.
MLA	USBC	2	0	1	36	31	0	1	40	45	4	13	0	22	36	31	87.6	509.	81.
GBI	SCTUV	2	0	1	37	8	0	1	41	17	4	8	0	22	37	8	38.8	507.	128.
GTI	SCTUV	2	0	1	39	33	0	1	42	39	3	5	0	22	39	33	10.5	504.	349.
BDA	SCTUV	2	0	1	40	31	0	1	43	21	2	50	0	22	40	31	9.1	512.	388.
ANT	CTUV	2	0	1	42	50	0	1	44	21	1	31	0	22	42	50	5.9	505.	474.
VAN	USBC	2	0	1	45	11	0	1	49	18	4	7	0	22	45	11	27.6	512.	172.
PRE	C	2	0	2	7	3	0	2	10	54	3	51	0	23	7	3	12.1	593.	392.
RED	USBCV	2	0	2	8	56	0	2	13	56	5	0	0	23	8	56	44.7	599.	147.
TAN	V	2	0	2	10	38	0	2	14	40	4	1	0	23	10	38	12.9	601.	382.
			0	2	22	9	MIDPOINT OF CIRCULARIZATION MANEUVER.												
CRO	USBCV	2	0	2	25	56	0	2	31	6	5	9	0	23	25	56	48.0	624.	145.
HAW	SCTUV	2	0	2	50	52	0	2	56	1	5	9	0	23	50	52	48.2	622.	144.
MER	USBC	2	0	2	56	1	0	3	0	58	4	57	0	23	56	1	25.5	628.	241.
CAL	CV	2	0	3	0	37	0	3	5	1	4	23	1	0	0	37	14.9	631.	363.
GDS	USB	2	0	3	1	34	0	3	5	40	4	6	1	0	1	34	12.6	631.	407.
GYM	S T V	2	0	3	2	22	0	3	7	36	5	14	1	0	2	22	59.9	628.	127.
WHS	C	2	0	3	3	26	0	3	8	21	4	55	1	0	3	26	25.1	628.	244.
TEX	S TUV	2	0	3	5	25	0	3	10	41	5	16	1	0	5	25	85.1	627.	111.
MLA	USBC	3	0	3	9	19	0	3	14	8	4	49	1	0	9	19	22.0	628.	271.
GBI	SCTUV	3	0	3	9	52	0	3	14	53	5	1	1	0	9	52	30.0	627.	211.
GTI	SCTUV	3	0	3	11	49	0	3	17	3	5	14	1	0	11	49	77.1	624.	112.
ANT	CTUV	3	0	3	14	22	0	3	19	36	5	13	1	0	14	22	89.1	623.	109.
ASC	USBCV	3	0	3	28	11	0	3	33	20	5	9	1	0	28	11	58.9	620.	128.
PRE	C	3	0	3	39	41	0	3	44	53	5	12	1	0	39	41	79.6	622.	110.
RED	USBCV	3	0	3	42	27	0	3	47	25	4	58	1	0	42	27	29.0	621.	214.
TAN	V	3	0	3	45	53	0	3	47	14	1	21	1	0	45	53	5.5	618.	598.
CRO	USBCV	3	0	4	1	3	0	4	2	27	1	23	1	1	1	3	5.5	624.	603.
GUA	USB	3	0	4	12	4	0	4	15	3	2	59	1	1	12	4	8.1	619.	511.
HAW	SCTUV	3	0	4	24	40	0	4	29	18	4	37	1	1	24	40	18.4	621.	308.

Table 8. AAP-1 (CSM) MSFN Coverage (5-degree Minimum Elevation) (Continued)

STATION NAME	STATION EQUIP	REV NO.	ACQUISITION D	ACQUISITION H	ACQUISITION M	ACQUISITION S	LOSS D	LOSS H	LOSS M	LOSS S	DURATION M	DURATION S	ACQ GMT D	ACQ GMT H	ACQ GMT M	ACQ GMT S	MAX ELEV DEGREES	ACQ RANGE N. MILES	MIN RANGE N. MILES
MER	USBC	3	0	4	30	4	0	4	34	24	4	19	1	1	30	4	14.2	628.	374.
CAL	CV	3	0	4	33	58	0	4	37	59	4	1	1	1	33	58	12.0	631.	419.
GDS	USB	3	0	4	35	4	0	4	38	21	3	16	1	1	35	4	8.8	631.	500.
GYM	S T V	3	0	4	35	52	0	4	41	2	5	10	1	1	35	52	44.1	628.	156.
WHS	C	3	0	4	37	12	0	4	41	0	3	48	1	1	37	12	10.9	628.	442.
TEX	S TUV	3	0	4	39	7	0	4	43	41	4	34	1	1	39	7	17.4	628.	324.
GTI	SCTUV	4	0	4	46	50	0	4	48	35	1	45	1	1	46	50	5.9	625.	590.
PRE	C	4	0	5	13	22	0	5	18	21	4	58	1	2	13	22	28.7	621.	215.
RED	USBCV	4	0	5	16	10	0	5	21	3	4	52	1	2	16	10	24.8	621.	242.
TAN	V	4	0	5	19	17	0	5	21	50	2	33	1	2	19	17	7.1	617.	541.
GUA	USB	4	0	5	44	23	0	5	49	25	5	2	1	2	44	23	35.5	618.	180.
HAW	SCTUV	4	0	5	58	53	0	6	2	42	3	49	1	2	58	53	11.0	621.	433.
MER	USBC	4	0	6	3	32	0	6	8	26	4	54	1	3	3	32	23.6	628.	256.
GYM	S T V	4	0	6	10	11	0	6	13	10	2	59	1	3	10	11	8.0	628.	522.
PRE	C	5	0	6	46	54	0	6	52	3	5	9	1	3	46	54	49.6	620.	140.
RED	USBCV	5	0	6	49	34	0	6	54	46	5	12	1	3	49	34	83.1	620.	109.
TAN	V	5	0	6	51	53	0	6	56	46	4	52	1	3	51	53	25.7	617.	254.
HAW	SCTUV	5	0	7	32	16	0	7	36	55	4	39	1	4	32	16	18.9	621.	300.
MER	USBC	5	0	7	36	55	0	7	42	3	5	7	1	4	36	55	36.7	628.	180.
PRE	C	6	0	8	20	30	0	8	25	14	4	43	1	5	20	30	21.1	620.	274.
RED	USBCV	6	0	8	23	45	0	8	27	9	3	24	1	5	23	45	9.4	620.	475.
TAN	V	6	0	8	25	31	0	8	29	55	4	23	1	5	25	31	15.9	617.	339.
HAW	SCTUV	6	0	9	5	33	0	9	10	41	5	8	1	6	5	33	45.1	622.	151.
GUA	USB	8	0	12	2	36	0	12	3	44	1	8	1	9	2	36	5.4	618.	604.
CTN	V	8	0	12	13	0	0	12	17	25	4	24	1	9	13	0	15.9	618.	339.
ASC	USBCV	9	0	12	52	52	0	12	57	57	5	5	1	9	52	52	45.5	615.	148.
GUA	USB	9	0	13	34	13	0	13	39	22	5	9	1	10	34	13	55.9	619.	129.
CTN	V	9	0	13	46	32	0	13	50	38	4	5	1	10	46	32	12.9	618.	390.
ASC	USBCV	10	0	14	28	7	0	14	29	23	1	15	1	11	28	7	5.4	615.	598.
GUA	USB	10	0	15	9	20	0	15	10	51	1	30	1	12	9	20	5.7	619.	593.
VAN	USBC	12	0	17	31	19	0	17	34	0	2	41	1	14	31	19	7.4	620.	534.
CYI	SCTUV	12	0	17	36	57	0	17	41	50	4	53	1	14	36	57	24.8	624.	244.
ANT	CTUV	13	0	18	58	55	0	19	3	57	5	2	1	15	58	55	36.7	618.	175.
VAN	USBC	13	0	19	3	19	0	19	8	31	5	11	1	16	3	19	85.4	620.	108.
CYI	SCTUV	13	0	19	10	9	0	19	15	23	5	13	1	16	10	9	69.1	624.	117.
CRO	USBCV	13	0	19	45	57	0	19	49	57	4	0	1	16	45	57	12.2	623.	408.
CNB	USB	13	0	19	54	29	0	19	58	8	3	39	1	16	54	29	10.4	625.	453.
GTI	SCTUV	14	0	20	30	34	0	20	35	44	5	10	1	17	30	34	61.2	619.	123.
GBI	SCTUV	14	0	20	30	38	0	20	33	36	2	57	1	17	30	38	8.0	622.	517.
ANT	CTUV	14	0	20	32	52	0	20	36	58	4	5	1	17	32	52	12.9	617.	390.
BDA	SCTUV	14	0	20	34	22	0	20	36	45	2	23	1	17	34	22	6.8	626.	560.
VAN	USBC	14	0	20	37	20	0	20	41	39	4	18	1	17	37	20	14.6	620.	381.
CYI	SCTUV	14	0	20	43	39	0	20	48	53	5	13	1	17	43	39	64.9	624.	120.

Table 8. AAP-1 (CSM) MSFN Coverage (5-degree Minimum Elevation)(Continued)

STATION NAME	STATION EQUIP	REV NO.	ACQUISITION D	ACQUISITION H	ACQUISITION M	ACQUISITION S	LOSS D	LOSS H	LOSS M	LOSS S	DURATION M	DURATION S	ACQ GMT D	ACQ GMT H	ACQ GMT M	ACQ GMT S	MAX ELEV DEGREES	ACQ RANGE N. MILES	MIN RANGE N. MILES
CRO	USBCV	14	0	21	18	39	0	21	23	51	5	12	1	18	18	39	70.7	622.	115.
CNB	USB	14	0	21	27	22	0	21	31	25	4	2	1	18	27	22	12.5	624.	404.
TEX	S TUV	14	0	21	59	40	0	22	2	54	3	13	1	18	59	40	8.7	623.	495.
MLA	USBC	15	0	22	2	30	0	22	7	24	4	53	1	19	2	30	25.2	623.	241.
GBI	SCTUV	15	0	22	2	45	0	22	7	55	5	10	1	19	2	45	54.8	622.	132.
GTI	SCTUV	15	0	22	4	28	0	22	8	54	4	25	1	19	4	28	15.7	619.	342.
BDA	SCTUV	15	0	22	6	17	0	22	11	2	4	44	1	19	6	17	20.4	626.	285.
VAN	USBC	15	0	22	11	25	0	22	15	11	3	46	1	19	11	25	10.8	620.	438.
CYI	SCTUV	15	0	22	17	10	0	22	22	8	4	58	1	19	17	10	27.9	624.	222.
CRO	USBCV	15	0	22	52	25	0	22	57	13	4	47	1	19	52	25	22.2	620.	264.
CNB	USB	15	0	23	1	30	0	23	3	20	1	49	1	20	1	30	6.0	623.	585.
CTN	V	15	0	23	12	18	0	23	16	31	4	13	1	20	12	18	14.2	612.	361.
GYM	S T V	15	0	23	29	21	0	23	33	50	4	29	1	20	29	21	16.6	622.	331.
WHS	C	16	0	23	31	19	0	23	34	27	3	7	1	20	31	19	8.4	623.	503.
TEX	S TUV	16	0	23	31	55	0	23	37	5	5	9	1	20	31	55	50.7	622.	139.
MLA	USBC	16	0	23	35	41	0	23	40	55	5	13	1	20	35	41	81.9	623.	110.
GBI	SCTUV	16	0	23	36	15	0	23	41	21	5	6	1	20	36	15	38.1	622.	172.
GTI	SCTUV	16	0	23	38	46	0	23	42	13	3	27	1	20	38	46	9.5	619.	472.
BDA	SCTUV	16	0	23	39	26	0	23	44	22	4	55	1	20	39	26	25.5	626.	240.
VAN	USBC	16	0	23	44	37	0	23	49	27	4	49	1	20	44	37	23.0	620.	257.
TAN	V	16	1	0	9	57	1	0	15	7	5	9	1	21	9	57	68.9	617.	115.
RED	USBCV	16	1	0	10	27	1	0	12	46	2	19	1	21	10	27	6.7	620.	557.
CRO	USBCV	16	1	0	25	58	1	0	30	56	4	58	1	21	25	58	29.2	619.	211.
CTN	V	16	1	0	45	40	1	0	49	51	4	10	1	21	45	40	13.9	612.	367.
HAW	SCTUV	16	1	0	53	19	1	0	53	54	0	34	1	21	53	19	5.1	616.	613.
			1	0	57	14	MIDPOINT OF PHASING MANEUVER.												
MER	USBC	16	1	0	55	53	1	1	0	58	5	5	1	21	55	53	38.7	623.	170.
CAL	CV	16	1	1	1	28	1	1	4	47	3	19	1	22	1	28	8.8	637.	516.
GYM	S T V	16	1	1	2	10	1	1	7	42	5	31	1	22	2	10	88.7	638.	119.
GDS	USB	16	1	1	2	18	1	1	5	36	3	17	1	22	2	18	8.6	642.	527.
WHS	C	16	1	1	3	27	1	1	8	41	5	13	1	22	3	27	24.8	648.	270.
TEX	S TUV	16	1	1	5	8	1	1	10	54	5	46	1	22	5	8	57.1	662.	151.
MLA	USBC	17	1	1	8	46	1	1	15	1	6	15	1	22	8	46	87.1	703.	142.
GBI	SCTUV	17	1	1	9	21	1	1	15	39	6	17	1	22	9	21	58.9	709.	167.
GTI	SCTUV	17	1	1	11	29	1	1	17	28	5	58	1	22	11	29	22.6	736.	356.
BDA	SCTUV	17	1	1	12	25	1	1	18	8	5	43	1	22	12	25	17.7	755.	437.
ANT	CTUV	17	1	1	14	10	1	1	19	57	5	47	1	22	14	10	16.7	773.	471.
VAN	USBC	17	1	1	17	13	1	1	24	27	7	14	1	22	17	13	41.1	822.	268.
ASC	USBCV	17	1	1	28	3	1	1	35	8	7	4	1	22	28	3	17.0	969.	812.

Table 8. AAP-1 (CSM) MSFN Coverage (5-degree Minimum Elevation)(Continued)

STATION NAME	EQUIP	REV NO.	ACQUISITION D	H	M	S	LOSS D	H	M	S	DURATION M	S	ACQ GMT D	H	M	S	MAX ELEV DEGREES	ACQ RANGE N. MILES	MIN RANGE N. MILES
			1	1	42	46	MIDPOINT OF CORRECTIVE COMBINATION MANEUVER.												
PRE	C	17	1	1	39	26	1	1	48	6	8	39	1	22	39	26	33.4	1060.	417.
RED	USBCV	17	1	1	41	50	1	1	50	59	9	8	1	22	41	50	74.8	1060.	255.
TAN	V	17	1	1	43	32	1	1	51	58	8	26	1	22	43	32	27.6	1057.	477.
CRO	USBCV	17	1	2	0	2	1	2	9	6	9	3	1	23	0	2	58.3	1059.	286.
			1	2	28	36	MIDPOINT OF NSR MANEUVER.												
HAW	SCTUV	17	1	2	26	29	1	2	35	36	9	7	1	23	26	29	81.7	1056.	248.
MER	USBC	17	1	2	31	57	1	2	40	54	8	56	1	23	31	57	42.4	1060.	354.
CAL	CV	17	1	2	36	37	1	2	45	19	8	42	1	23	36	37	33.0	1064.	427.
GDS	USB	17	1	2	37	32	1	2	46	4	8	31	1	23	37	32	28.8	1065.	471.
GYM	S T V	17	1	2	38	42	1	2	47	56	9	14	1	23	38	42	77.4	1064.	256.
WHS	C	17	1	2	39	45	1	2	48	45	9	0	1	23	39	45	44.5	1065.	345.
TEX	S TUV	17	1	2	41	55	1	2	51	12	9	16	1	23	41	55	84.9	1067.	252.
MLA	USBC	18	1	2	45	59	1	2	54	55	8	55	1	23	45	59	37.2	1072.	396.
GBI	SCTUV	18	1	2	46	37	1	2	55	41	9	4	1	23	46	37	44.3	1072.	350.
GTI	SCTUV	18	1	2	48	43	1	2	58	1	9	18	1	23	48	43	68.6	1072.	271.
BDA	SCTUV	18	1	2	50	50	1	2	56	20	5	30	1	23	50	50	9.6	1080.	893.
ANT	CTUV	18	1	2	51	24	1	3	0	44	9	20	1	23	51	24	71.6	1074.	267.
			1	2	58	55	MIDPOINT OF TPI MANEUVER.												
VAN	USBC	18	1	2	56	40	1	3	2	24	5	44	1	23	56	40	10.1	1082.	879.
ASC	USBCV	18	1	3	6	5	1	3	15	29	9	24	2	0	6	5	54.9	1092.	313.
PRE	C	18	1	3	18	18	1	3	27	56	9	37	2	0	18	18	75.6	1107.	273.
RED	USBCV	18	1	3	21	15	1	3	30	44	9	28	2	0	21	15	49.5	1108.	340.
TAN	V	18	1	3	23	47	1	3	31	48	8	0	2	0	23	47	18.4	1107.	666.
			1	3	35	36	MIDPOINT OF BRAKING MANEUVER.												
CRO	USBCV	18	1	3	40	17	1	3	47	26	7	8	2	0	40	17	14.4	1101.	756.
GUA	USB	18	1	3	52	8	1	4	0	53	8	44	2	0	52	8	30.6	1085.	460.
HAW	SCTUV	18	1	4	6	27	1	4	15	25	8	57	2	1	6	27	34.3	1083.	425.
MER	USBC	18	1	4	12	4	1	4	21	3	8	59	2	1	12	4	32.7	1090.	446.
CAL	CV	18	1	4	16	4	1	4	24	43	8	39	2	1	16	4	26.5	1096.	522.
GDS	USB	18	1	4	17	3	1	4	25	17	8	13	2	1	17	3	21.3	1097.	605.
GYM	S T V	18	1	4	18	23	1	4	27	49	9	25	2	1	18	23	54.6	1096.	317.

Table 8. AAP-1 (CSM) MSFN Coverage (5-degree Minimum Elevation)(Continued)

STATION NAME	STATION EQUIP	REV NO.	ACQUISITION D	ACQUISITION H	ACQUISITION M	ACQUISITION S	LOSS D	LOSS H	LOSS M	LOSS S	DURATION M	DURATION S	ACQ GMT D	ACQ GMT H	ACQ GMT M	ACQ GMT S	MAX ELEV DEGREES	ACQ RANGE N. MILES	MIN RANGE N. MILES
WHS	C	18	1	4	19	31	1	4	27	57	8	26	2	1	19	31	25.3	1098.	591.
TEX	S TUV	18	1	4	21	46	1	4	30	40	8	54	2	1	21	46	30.0	1100.	480.
MLA	USBC	19	1	4	26	48	1	4	32	55	6	7	2	1	26	48	10.7	1107.	879.
GRI	SCTUV	19	1	4	27	21	1	4	33	52	6	31	2	1	27	21	11.8	1107.	843.
GTI	SCTUV	19	1	4	29	21	1	4	36	33	7	11	2	1	29	21	14.2	1108.	773.
ANT	CTUV	19	1	4	32	20	1	4	39	6	6	45	2	1	32	20	12.5	1110.	824.
ASC	USBCV	19	1	4	47	40	1	4	54	14	6	34	2	1	47	40	11.7	1118.	854.
PRE	C	19	1	4	58	28	1	5	8	1	9	32	2	1	58	28	52.8	1116.	328.
RED	USBCV	19	1	5	1	26	1	5	10	57	9	30	2	2	1	26	52.6	1114.	327.
TAN	V	19	1	5	4	2	1	5	12	39	8	37	2	2	4	2	24.3	1109.	555.
GUA	USB	19	1	5	31	53	1	5	40	54	9	1	2	2	31	53	38.6	1082.	388.
HAW	SCTUV	19	1	5	46	56	1	5	55	42	8	45	2	2	46	56	28.3	1087.	491.
MER	USBC	19	1	5	52	4	1	6	1	32	9	28	2	2	52	4	57.5	1096.	307.
CAL	CV	19	1	5	56	39	1	6	2	57	6	17	2	2	56	39	11.3	1103.	857.
GDS	USB	19	1	5	58	8	1	6	2	50	4	42	2	2	58	8	8.0	1105.	978.
GYM	S T V	19	1	5	58	54	1	6	6	32	7	37	2	2	58	54	16.5	1104.	712.
WHS	C	19	1	6	1	23	1	6	4	49	3	25	2	3	1	23	6.5	1107.	1043.
TEX	S TUV	19	1	6	3	46	1	6	7	38	3	51	2	3	3	46	6.9	1110.	1028.
PRE	C	20	1	6	38	32	1	6	48	9	9	36	2	3	38	32	87.2	1111.	264.

Table 9. Discrete Events Summary/First and Second Periods of Activities

Event	CSM Revolution Number	Time of Burn Initiation (g.e.t.) (hr:min:sec)	Maneuver ΔV[1] ΔVX	ΔVY	ΔVZ	Burn Time (sec)	Total ΔV (ft/sec)	Vehicle	Thruster	Resultant Apogee/Perigee Altitude above Spherical Earth (n mi)	Location at Midpoint of Burn: Geocentric Latitude (deg)	Longitude (deg)	Lighting Conditions
AAP-1 Liftoff	1	00:00:00						CSM			28.36	-80.56	DAY
AAP-1 Insertion	1	00:10:03.0						CSM		110/81	28.60	-61.67	DAY
AAP-1 Circularization	2	02:22:09.4	53.2	0.0	1.8	2.1	53.2	CSM	SPS	110/110	-28.46	86.46	DAY
AAP-2 Liftoff	15	23:24:15.0						OWS			28.37	-80.56	DAY
AAP-2 Insertion	16	23:34:02.6						OWS		260/260	28.81	-65.71	DAY
AAP-2 Passivation	16	23:35:13.0	13.3	0.0	-41.8		43.9	OWS	J-2 Dump	270/257	28.56	-60.90	DAY
Phasing Maneuver	16	24:57:08.6	242.8	0.0	0.0	10.4	242.8	CSM	SPS	248/109	19.36	-14.14	DAY
Corrective Combination Maneuver	17	25:42:41.3	239.5	0.0	-0.4	10.0	239.5	CSM	SPS	248/247	-19.50	27.36	DARK
Coelliptical Maneuver	17	26:28:09.5	21.1	0.6	1.6	47.7	21.2	CSM	RCS	260/247	18.18	-16.78	DAY
Terminal Phase Initiation	18	26:58:34.2	18.3	-2.0	-7.2	44.3	19.7	CSM	RCS	266/251	10.95	-52.62	DARK
Braking (TPF)	18	27:35:10.4	16.9	3.7	15.6	52.2	23.3	CSM	RCS	270/257	-25.47	78.77	DAY

[1] Maneuver ΔV
ΔVX - Positive in direction of motion
ΔVZ - Positive downward along gravity gradient
ΔVY - Completes right hand coordinate system established at scheduled time of burn initiation

Note: Ullage begins 17 seconds prior to burn initiation on SPS thruster.

Table 10. Orbital Elements Following the Nominal Maneuvers

A-SEMI-MAJOR AXIS (INT.FT)
E-ECCENTRICITY
I-INCLINATION (DEG)
G-ARGUMENT OF PERIGEE (DEG)
H-INERTIAL ASCENDING NODE*(DEG)
L-MEAN ANOMALY (DEG)

V -INERTIAL VELOCITY
G -INERTIAL FLIGHT-PATH ANGLE(DEG)
P -INERTIAL HEADING ANGLE (DEG)
R -RADIUS (INT.FT)
LO-EARTH FIXED LONGITUDE (DEG)
LA-GEOCENTRIC LATITUDE (DEG)

X,Y,Z COMPONENTS OF VEHICLE POSITION IN EARTH CENTERED,RIGHT HANDED, INERTIAL COORDINATE SYSTEM. SYSTEM ORIENTATED AT GMT=0 WITH X-Z PLANE THROUGH ZERO LONGITUDE AND X-Y PLANE CONTAINING THE EQUATOR. THE Z AXIS PASSES THROUGH THE NORTH POLE (FT)

XD,YD,ZD VELOCITY COMPONENTS IN THE ABOVE INERTIAL COORDINATE SYSTEM (FT/SEC)

CSM INSERTION VECTOR

DAY HOUR MIN SEC						
	A =	0.21505981E 08	V =	0.25707861E 05	X =	-0.40200363E 07
	E =	0.48299113E-02	G =	-0.18043037E-05	Y =	-0.10287570E 08
GMT 00:21:10:03.0	I =	0.28860004E 02	P =	0.94048617E 02	Z =	0.10244625E 08
	G =	0.97379546E 02	R =	0.21402110E 08	XD=	0.24757061E 05
	H =	0.15829723E 03	LO=	-0.61672998E 02	YD=	-0.67410637E 04
	L =	0.35909963E 03	LA=	0.28598810E 02	ZD=	-0.15936705E 04

CSM CIRCULARIZATION MANEUVER

	A =	0.21592865E 08	V =	0.25551760E 05	X =	0.39523031E 07
	E =	0.75525069E-03	G =	-0.38174725E-04	Y =	0.10551105E 08
GMT 00:23:22:09.4	I =	0.28658749E 02	P =	0.85016902E 02	Z =	-0.10292611E 08
	G =	-0.80846065E 02	R =	0.21576557E 08	XD=	-0.24674064E 05
	H =	0.15758737E 03	LO=	0.86456388E 02	YD=	0.65463147E 04
	L =	0.35904950E 03	LA=	-0.28461638E 02	ZD=	0.15612240E 04

OWS INSERTION VECTOR

	A =	0.22409820E 08	V =	0.25023808E 05	X =	-0.64479050E 07
	E =	0.44802721E-03	G =	-0.30913550E-07	Y =	-0.17985440E 08
GMT 01:20:34:02.6	I =	0.28869927E 02	P =	0.91959056E 02	Z =	0.10837014E 08
	G =	0.93558060E 02	R =	0.22409720E 08	XD=	0.22402050E 05
	H =	0.15056686E 03	LO=	-0.65712060E 02	YD=	-0.11098772E 05
	L =	0.35909994E 03	LA=	0.28809056E 02	ZD=	-0.74279705E 03

* X-AXIS REFERENCED THROUGH GREENWICH MERIDIAN AT MIDNIGHT (GMT=0) PRIOR TO LAUNCH.

Table 11. Discrete Events Summary/Fourth Period of Activities

Event	Time From AAP-1 Lift-off (day:hr:min:sec:)	Altitude (ft)	Geodetic Latitude[1] (deg)	Longitude[1] (deg)	Inertial Velocity (ft/sec)	Inertial Azimuth[2] (deg)	Inertial Flight Path Angle[3] (deg)
CSM Deorbit							
RCS Ignition	25:12:26:54	1,566,383	8.921	-172.487	25,039	62.380	0.057
SPS Ignition	25:12:27:11	1,566,941	9.425	-171.584	25,033	62.535	0.041
CM Entry							
Entry Interface	25:12:49:44	400,000	27.315	-83.302	25,983	100.187	-1.891
Drogue Chute Deployment	25:12:57:28	23,500	21.197	-60.486	15,196	90.352	-17.960
Main Chute Deployment	25:12:57:53	10,200	21.197	-60.485	1,511	90.118	-18.893
CM Splashdown	25:13:00:22	0	21.197	-60.484	1,424	90.000	-2.410

(1) **Minus** coordinates indicate west longitudes and south latitudes

(2) **Measured positive eastward from north**

(3) **Measured positive above the local horizontal**

Table 10. Orbital Elements Following the Nominal Maneuvers (Continued)

OWS PASSIVATION

DAY HOUR MIN SEC						
	A =	0.22524130E 08	V =	0.25037298E 05	X =	-0.68403992E 07
	E =	0.22657881E-02	G =	0.95868815E-01	Y =	-0.18531086E 08
	I =	0.28870433E 02	P =	0.94419231E 02	Z =	0.10751520E 08
GMT 01:20:35:13.0	G =	0.50360203E 02	R =	0.22489718E 08	XD=	0.23086174E 05
	H =	0.15055638E 03	LO=	-0.60895887E 02	YD=	-0.95441619E 04
	L =	0.47505649E 02	LA=	0.28559022E 02	ZD=	-0.16744489E 04

PHASE ADJUSTMENT MANEUVER (NC1)

	A =	0.22014900E 08	V =	0.25802880E 05	X =	-0.20051521E 08
	E =	0.20210707E-01	G =	0.17521105E-02	Y =	-0.34740895E 07
	I =	0.28876830E 02	P =	0.68147225E 02	Z =	0.71505627E 07
GMT 01:21:57:13.8	G =	0.43261209E 02	R =	0.21569963E 08	XD=	0.72248581E 04
	H =	0.15025177E 03	LO=	-0.14136545E 03	YD=	-0.23053800E 05
	L =	0.84923157E-01	LA=	0.19360182E 02	ZD=	0.90615854E 04

CORRECTIVE COMBINATION MANEUVER (NCC)

	A =	0.22431812E 08	V =	0.25070581E 05	X =	0.20809275E 08
	E =	0.82855083E-03	G =	-0.11755795E-01	Y =	0.36569098E 07
	I =	0.28878460E 02	P =	0.11173148E 03	Z =	-0.74819590E 07
GMT 01:22:42:46.4	G =	-0.12192667E 03	R =	0.22413805E 08	XD=	-0.70875034E 04
	H =	0.15002129E 03	LO=	0.27355560E 02	YD=	0.22400152E 05
	L =	0.34567421E 03	LA=	-0.19500209E 02	ZD=	-0.87484004E 04

CO-ELLIPTICAL MANEUVER (NSR)

	A =	0.22471362E 08	V =	0.25099103E 05	X =	-0.21160259E 08
	E =	0.28206091E-02	G =	-0.13331584E-02	Y =	-0.23467598E 07
	I =	0.28881958E 02	P =	0.67160728E 02	Z =	0.69895470E 07
GMT 01:23:28:36.4	G =	0.40699127E 02	R =	0.22407981E 08	XD=	0.55705473E 04
	H =	0.14980437E 03	LO=	-0.16777304E 03	YD=	-0.22655288E 05
	L =	-0.47131678E 00	LA=	0.18175111E 02	ZD=	0.92559092E 04

TERMINAL PHASE INITIATION (TPI)

	A =	0.22507590E 08	V =	0.25049212E 05	X =	0.13907496E 08
	E =	0.26273545E-02	G =	0.11777924E 00	Y =	-0.17126131E 08
	I =	0.28893879E 02	P =	0.11690654E 03	Z =	0.42675981E 07
GMT 01:23:58:55.0	G =	0.10525724E 03	R =	0.22470762E 08	XD=	0.18729135E 05
	H =	0.14959672E 03	LO=	-0.52620791E 02	YD=	0.12370837E 05
	L =	0.51362691E 02	LA=	0.10947961E 02	ZD=	-0.11119573E 05

VELOCITY MATCH AT RENDEZVOUS (TPF)

	A =	0.22526859E 08	V =	0.25007703E 05	X =	0.12012977E 06
	E =	0.17764888E-02	G =	-0.99096547E-01	Y =	0.20328379E 08
	I =	0.28876551E 02	P =	0.75919070E 02	Z =	-0.96845398E 07
GMT 02:00:35:35.6	G =	0.13953319E 02	R =	0.22517721E 08	XD=	-0.24240605E 05
	H =	0.14941037E 03	LO=	0.78767668E 02	YD=	0.27209577E 04
	L =	-0.76702042E 02	LA=	-0.25472970E 02	ZD=	0.55113191E 04

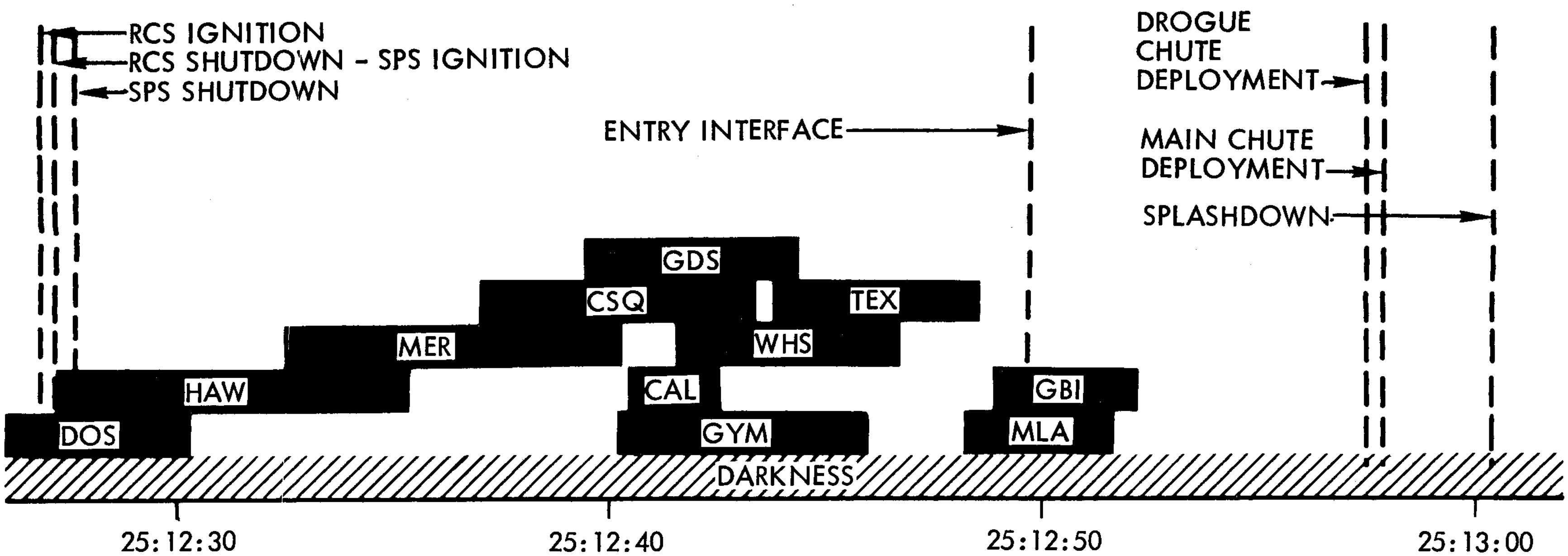


Figure 1. Major Event Timeline/AAP-1 MSFN Coverage, Deorbit to Splashdown

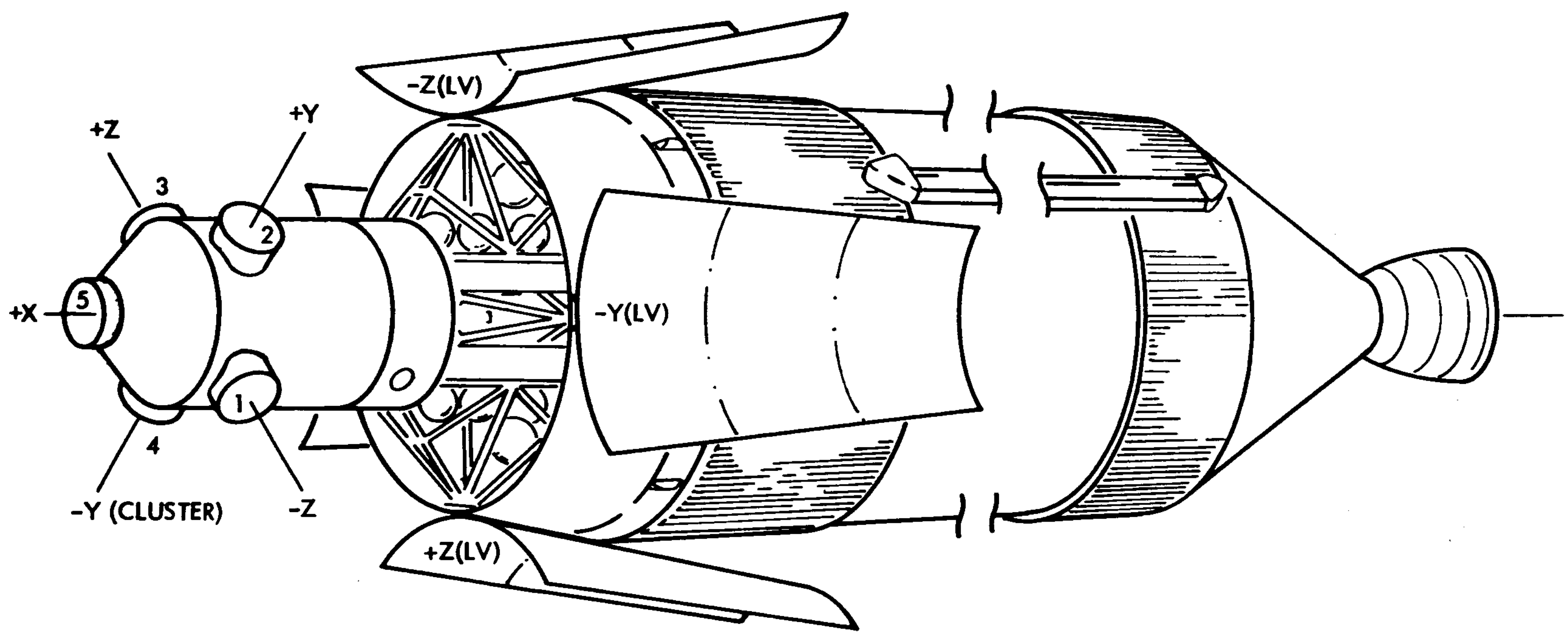


Figure 2. AAP-Orbital Workshop Showing Launch Vehicle and Cluster Coordinate Systems (Solar Panels Not Shown Deployed)

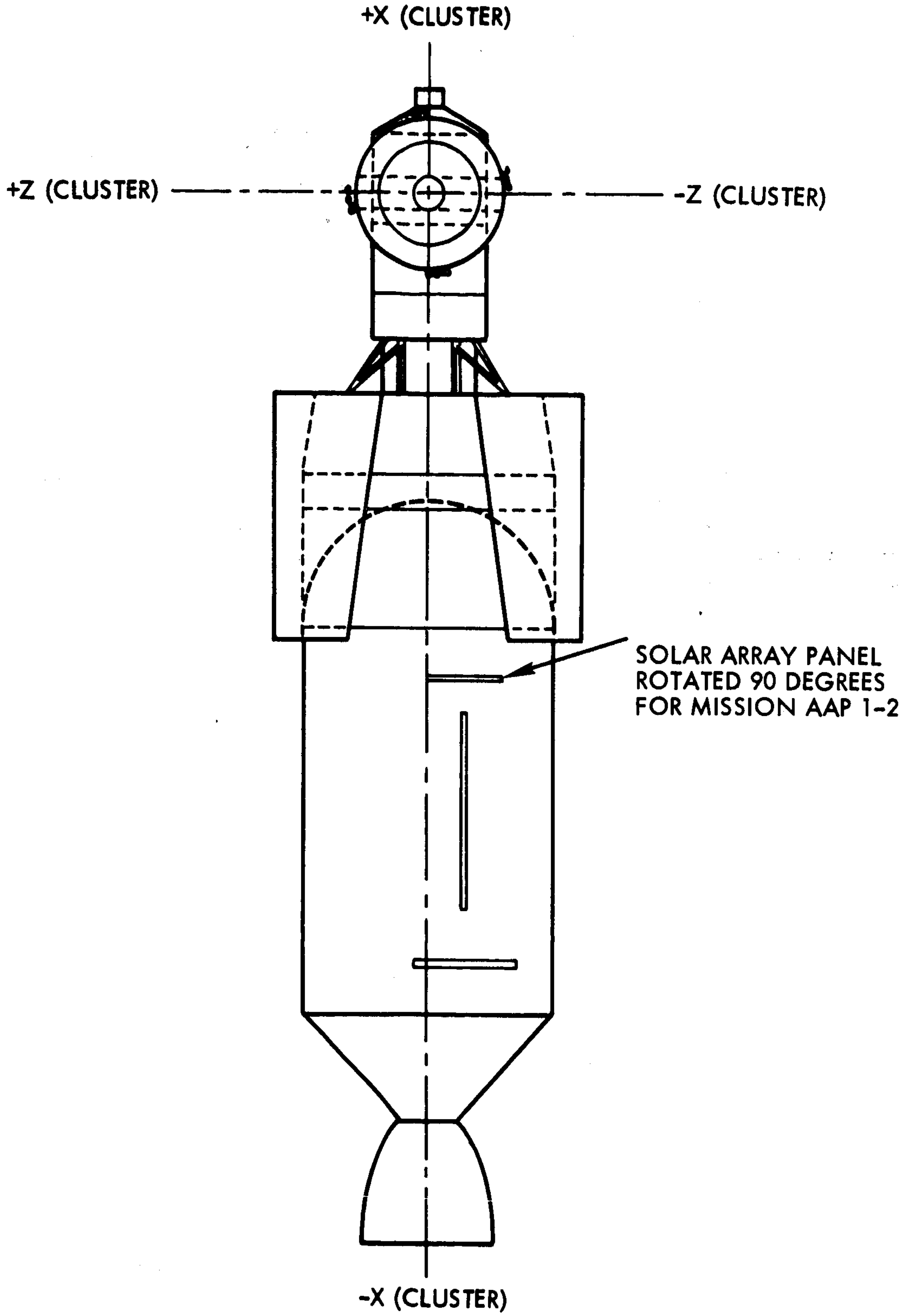


Figure 3. AAP-1/2 Spacecraft Cluster Configuration (CSM Broadside)

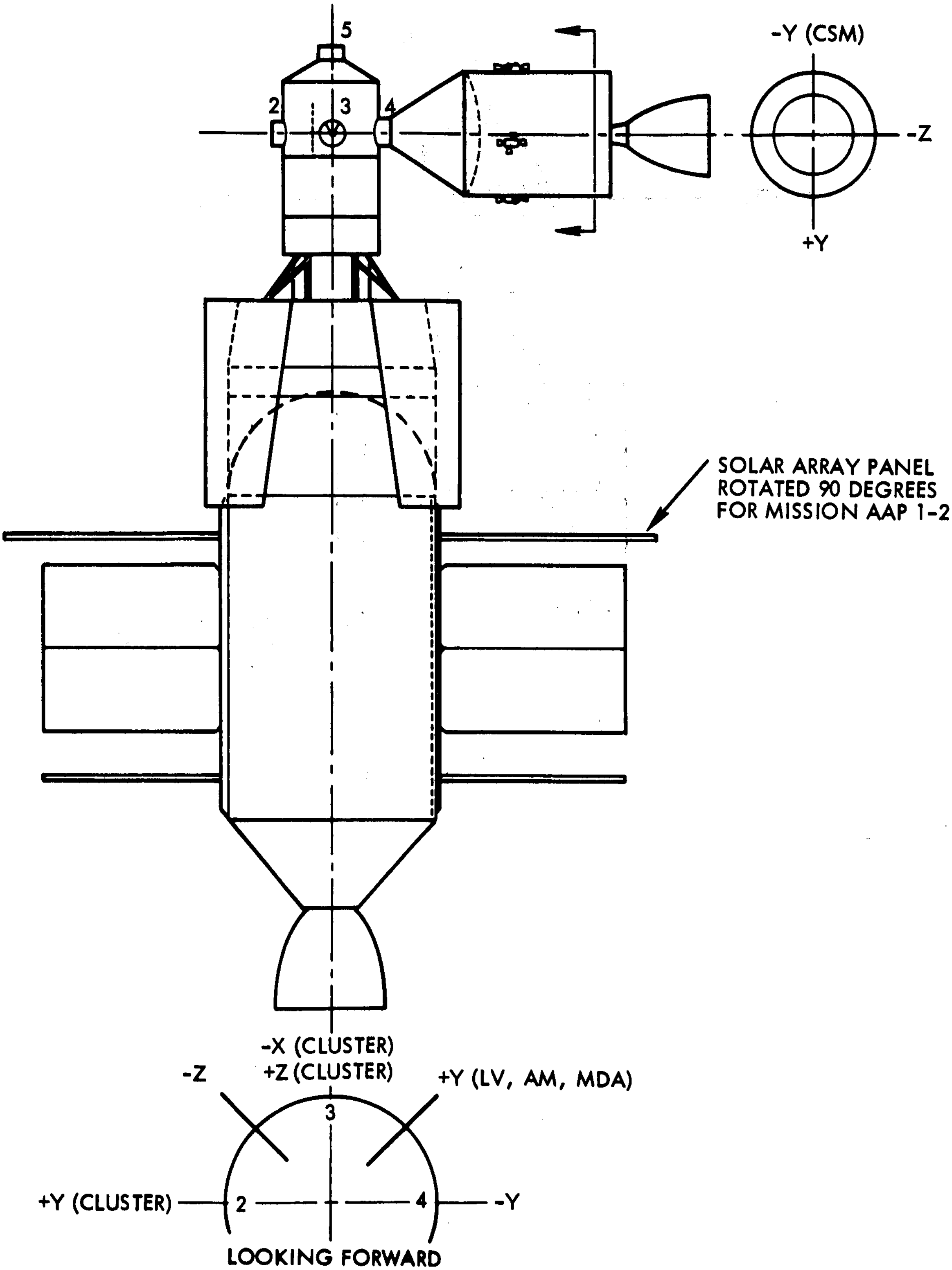


Figure 4. AAP-1/2 Spacecraft Cluster Configuration (CSM Head-on)

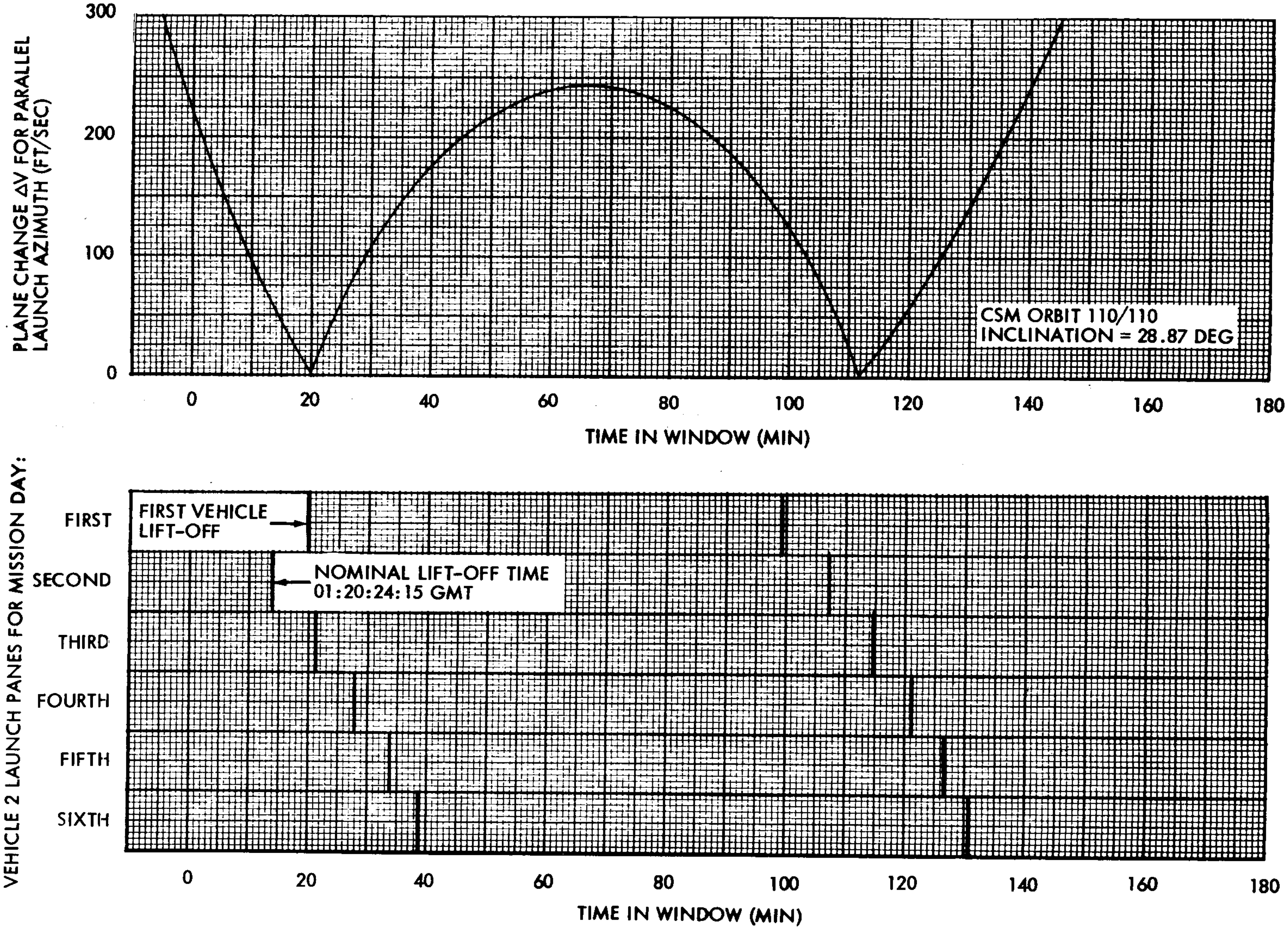


Figure 5. Launch Window for AAP-2 Mission

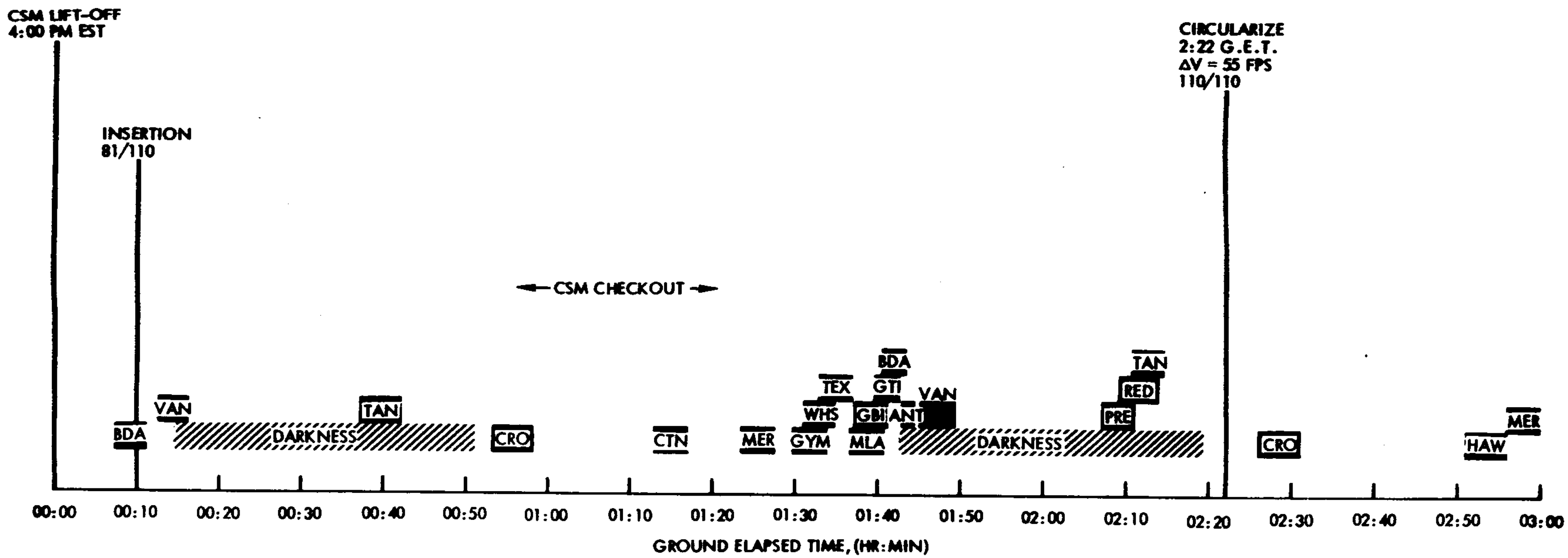
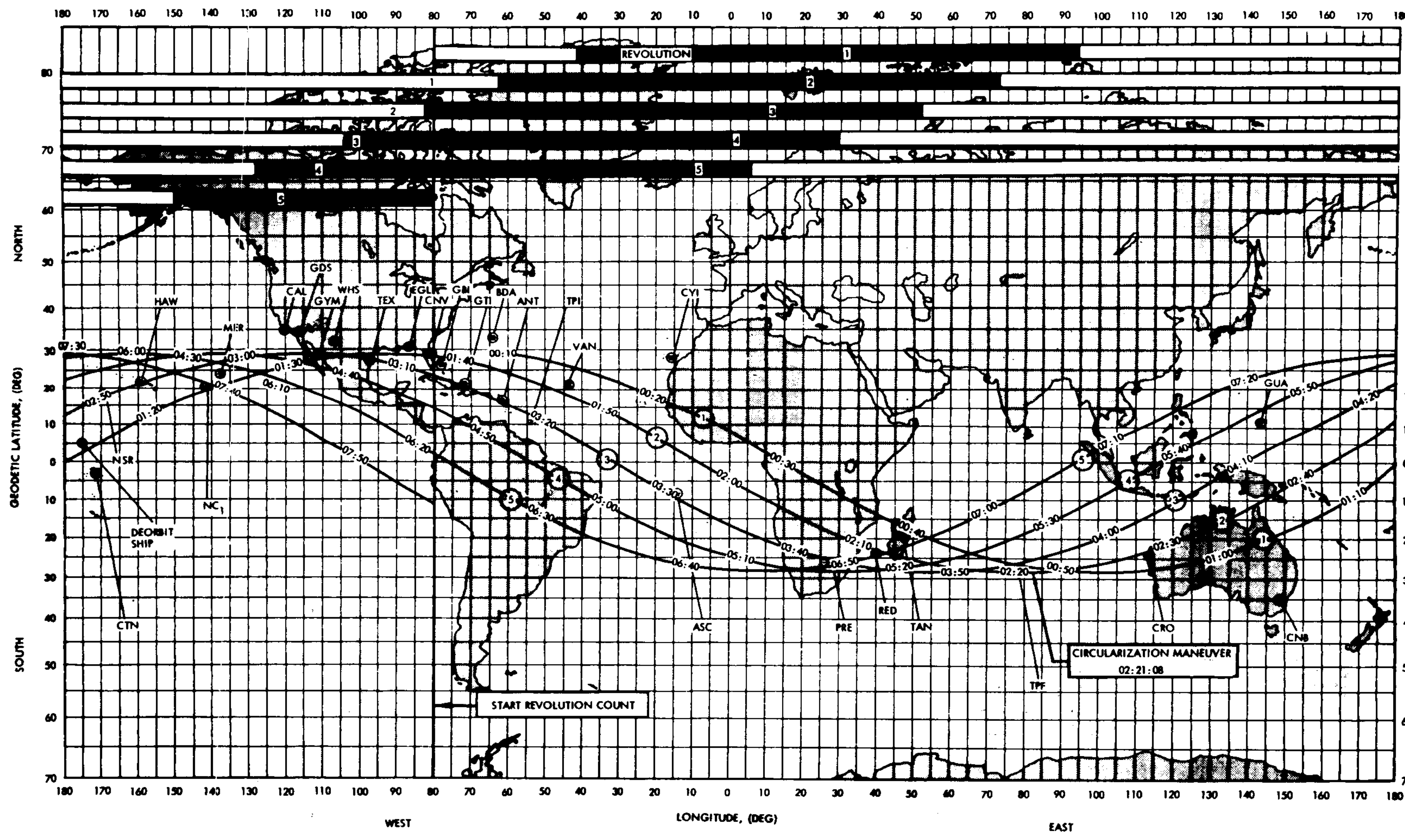


Figure 6. Major Event Timeline/AAP-1 MSFN Coverage/First Period of Activities



(A) REVOLUTIONS 1 THROUGH 5.

Figure 7. AAP-1 Earth Ground Track/First Period of Activities

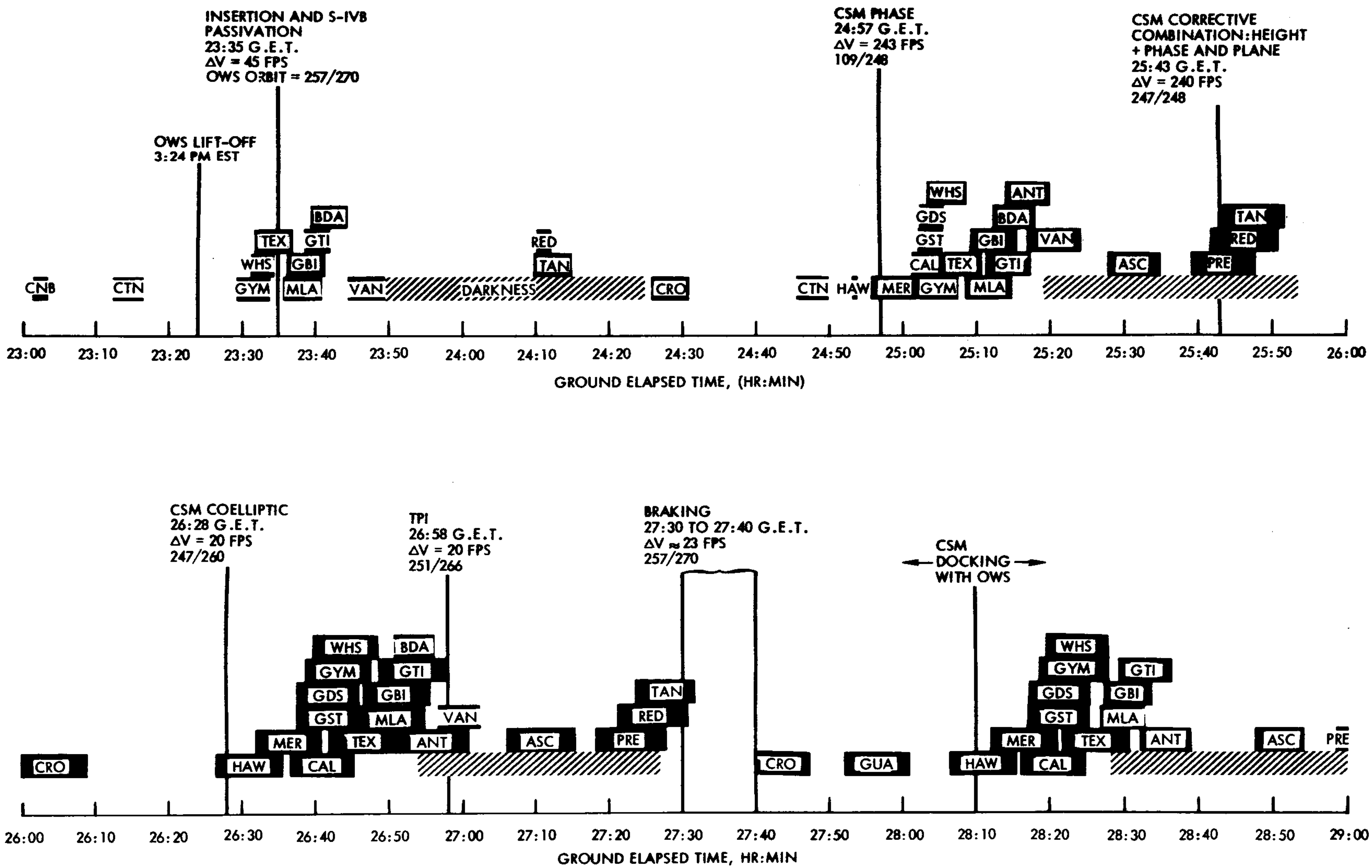


Figure 8. Major Event Timeline/AAP-1 MSFN Coverage/Second Period of Activities

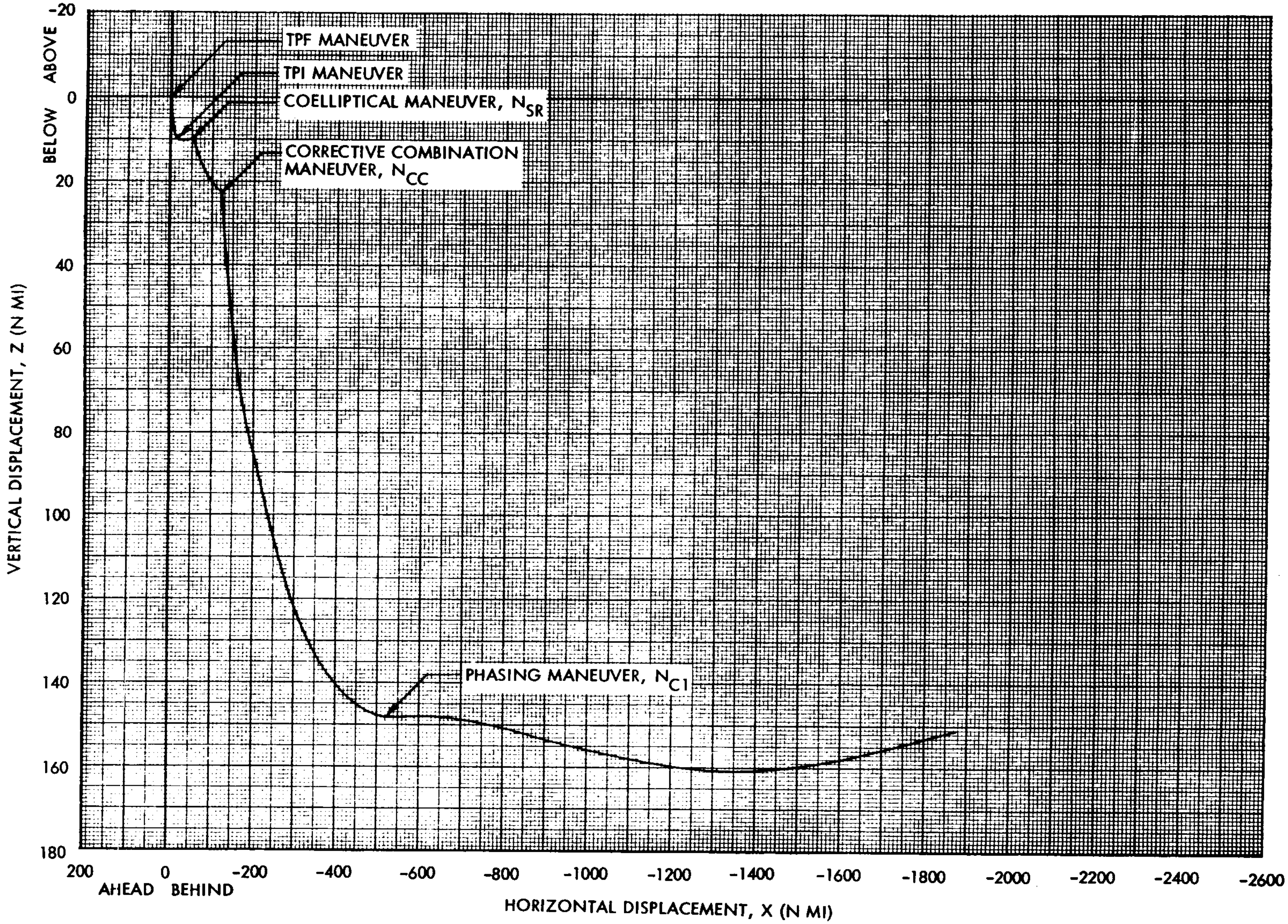


Figure 9a. AAP-1/AAP-2 Relative Motion from OWS Insertion to CSM Rendezvous with OWS

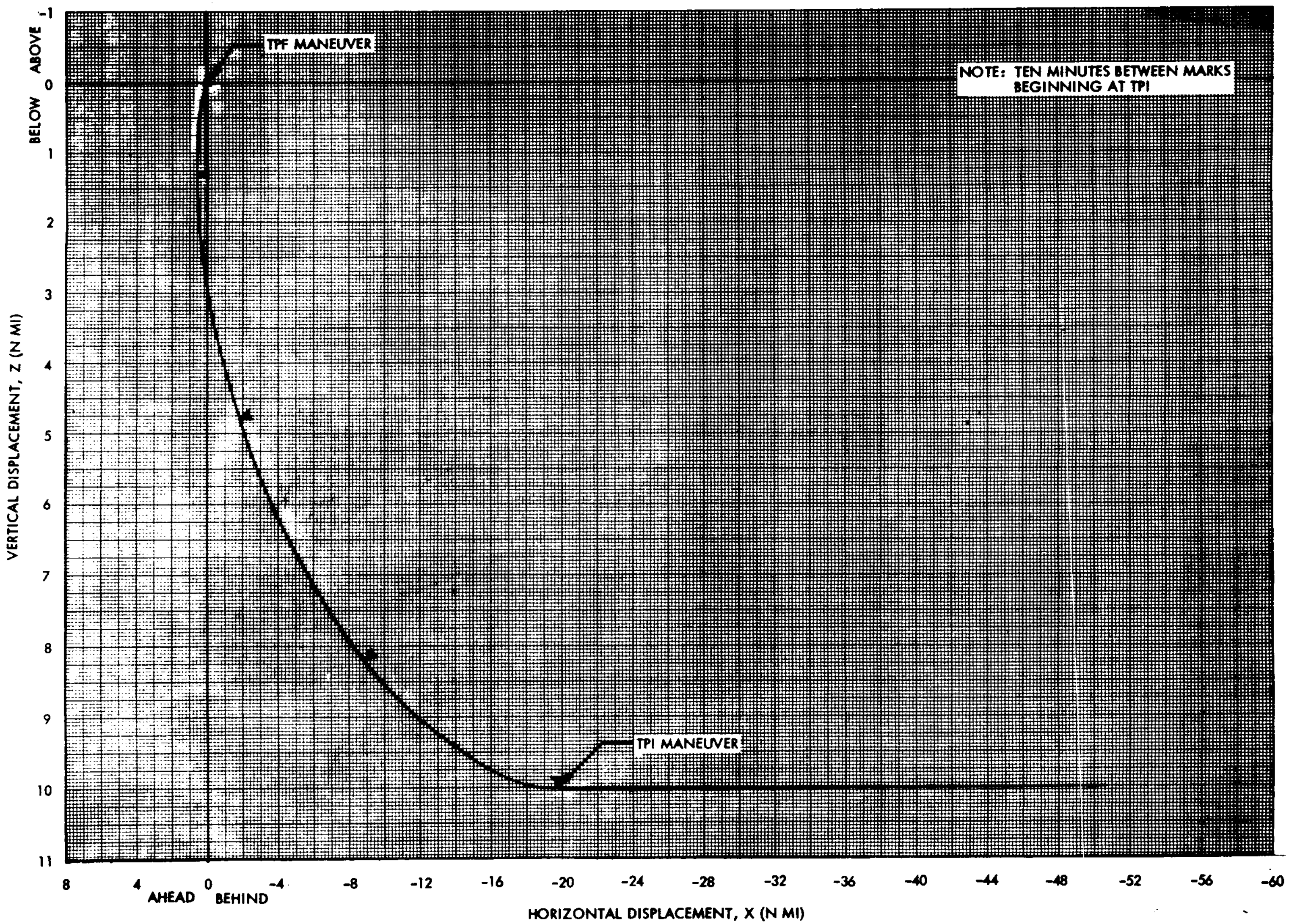


Figure 9b. AAP-1/AAP-2 Relative Motion from TPI to CSM Rendezvous with OWS

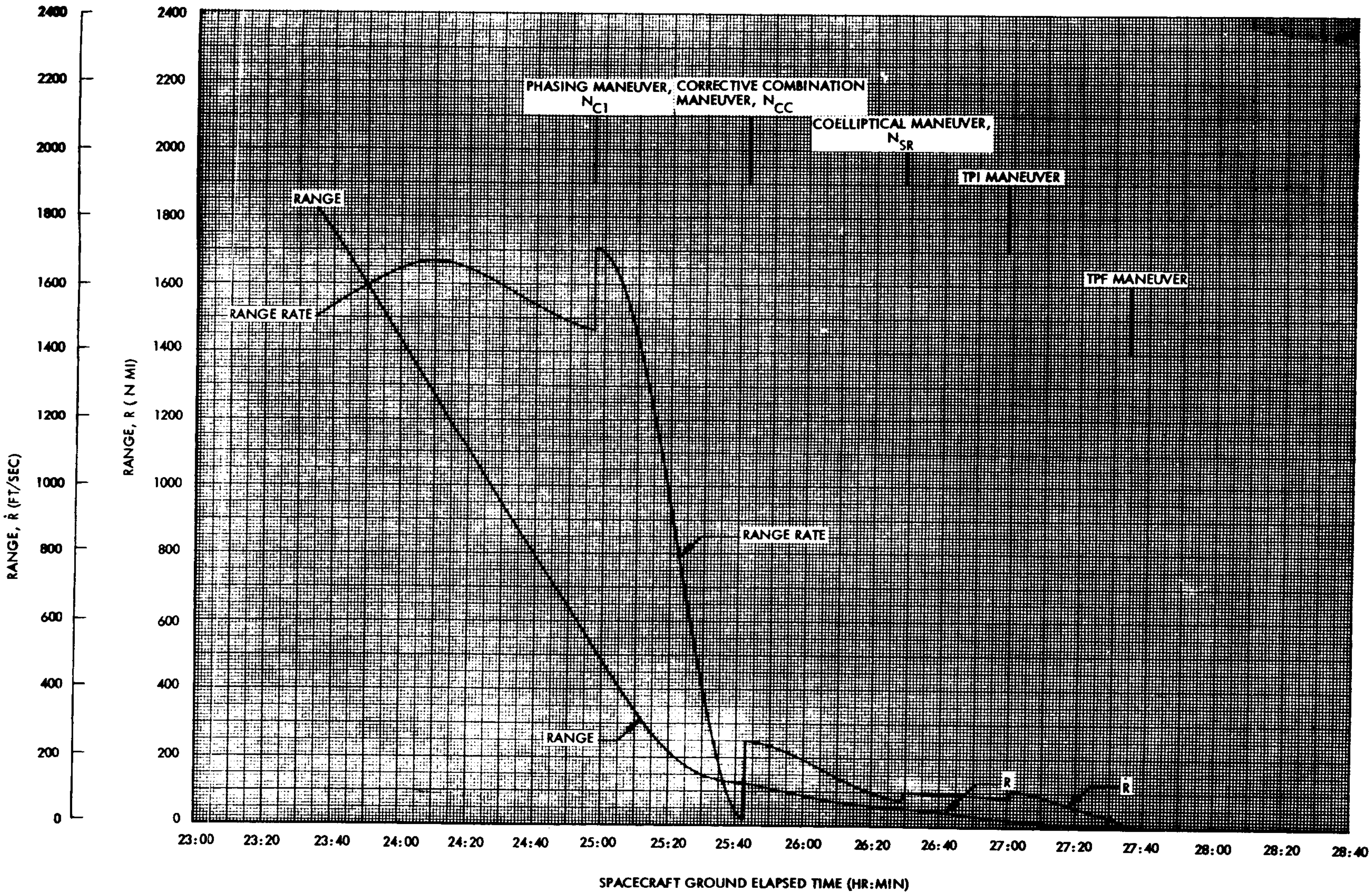


Figure 10a. AAP-1/AAP-2 Relative Range and Range Rate from OWS Insertion to CSM Rendezvous with OWS

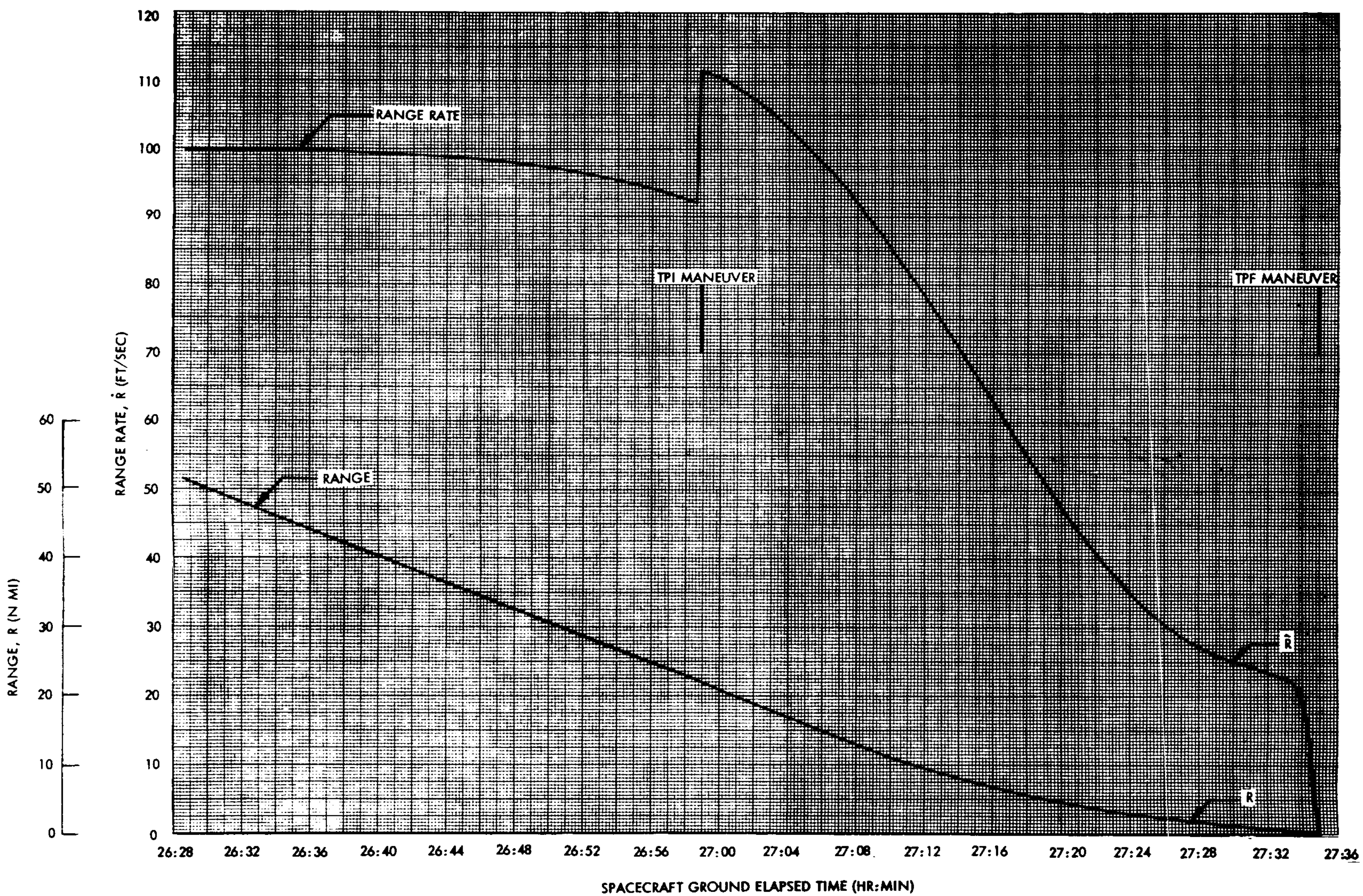


Figure 10b. AAP-1/AAP-2 Relative Range and Range Rate from OWS Insertion to CSM Rendezvous with OWS

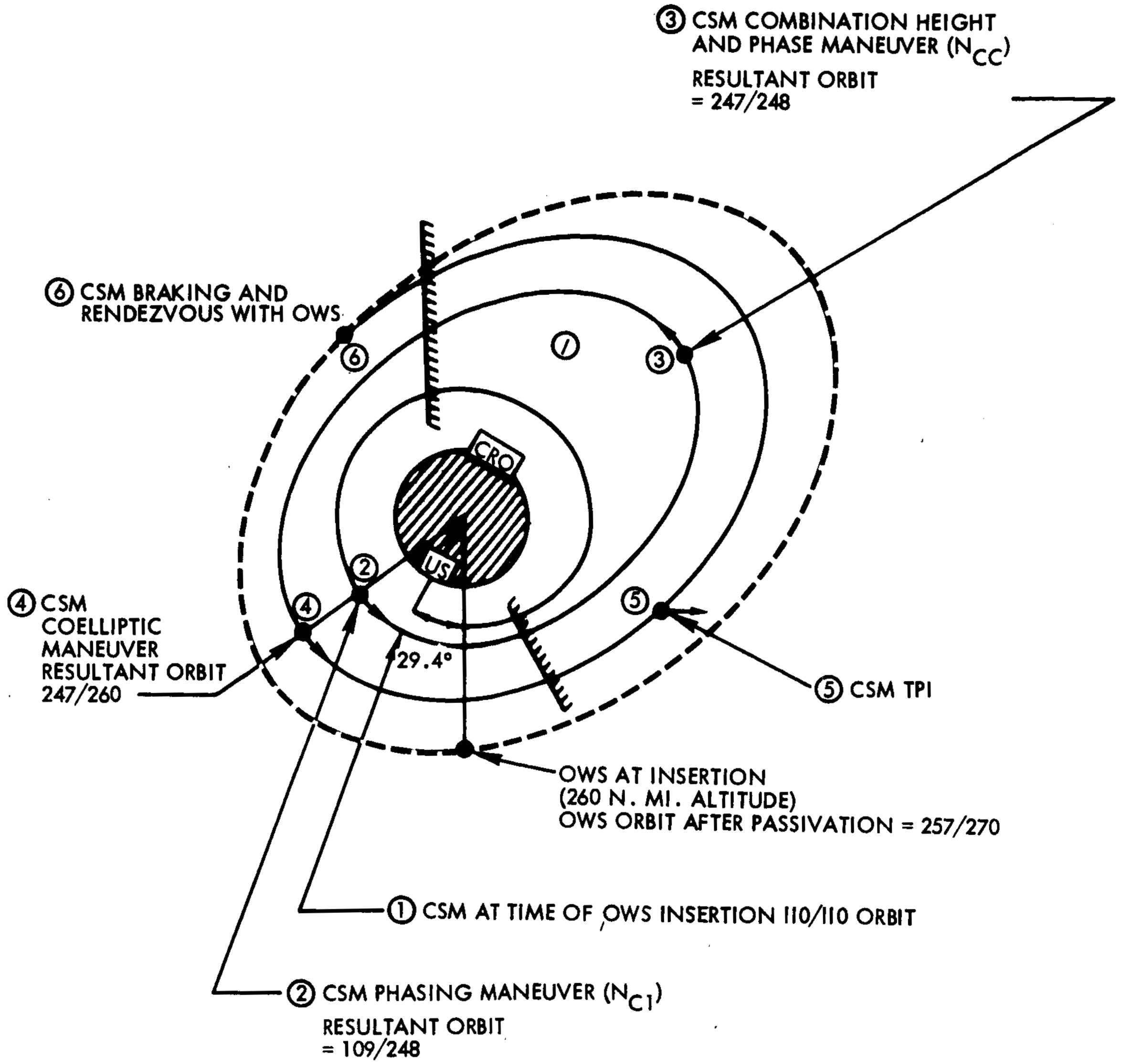


Figure 11. Orbital Geometry/Second Period of Activities

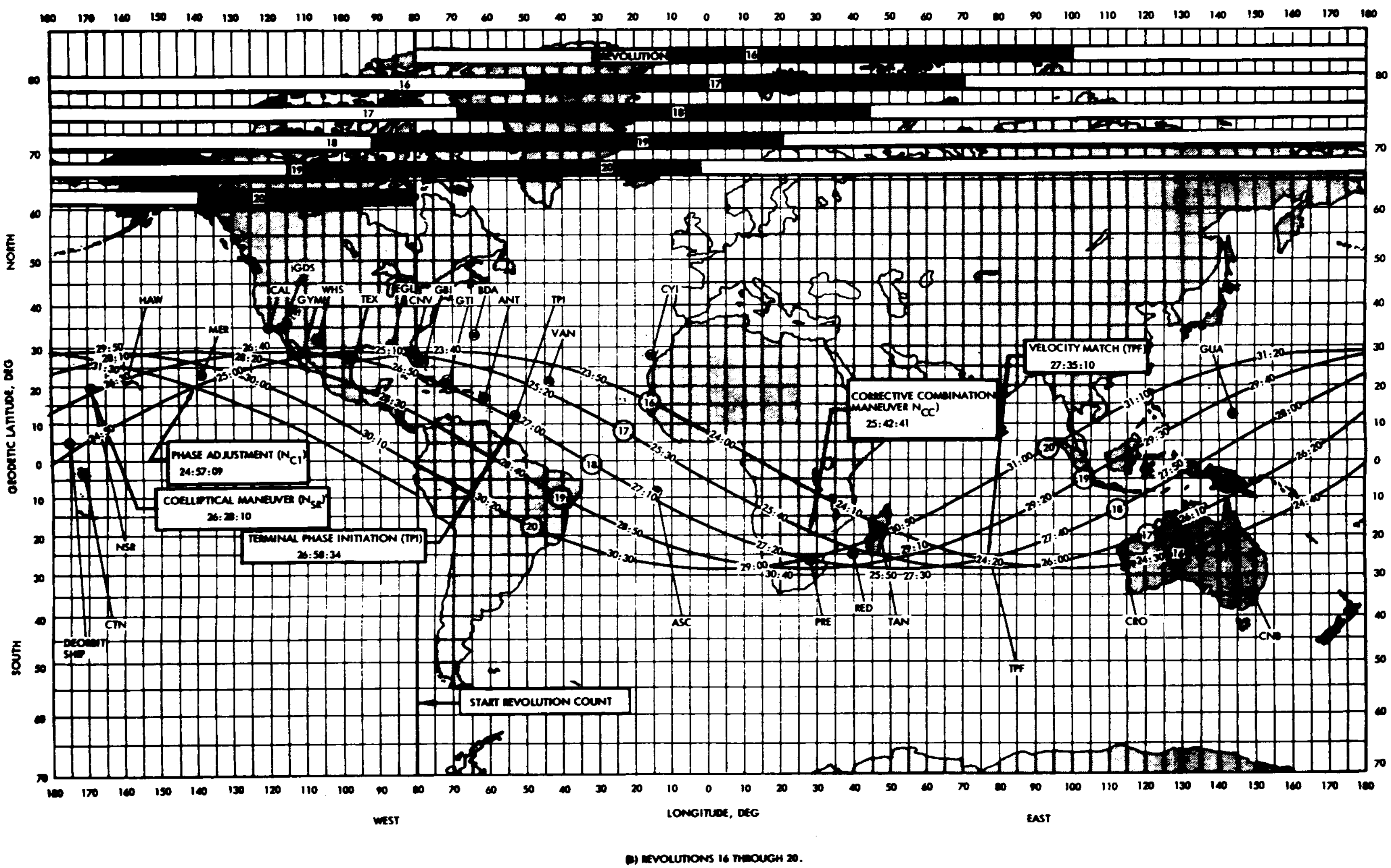


Figure 12. AAP-1 Earth Ground Track/Second Period of Activities

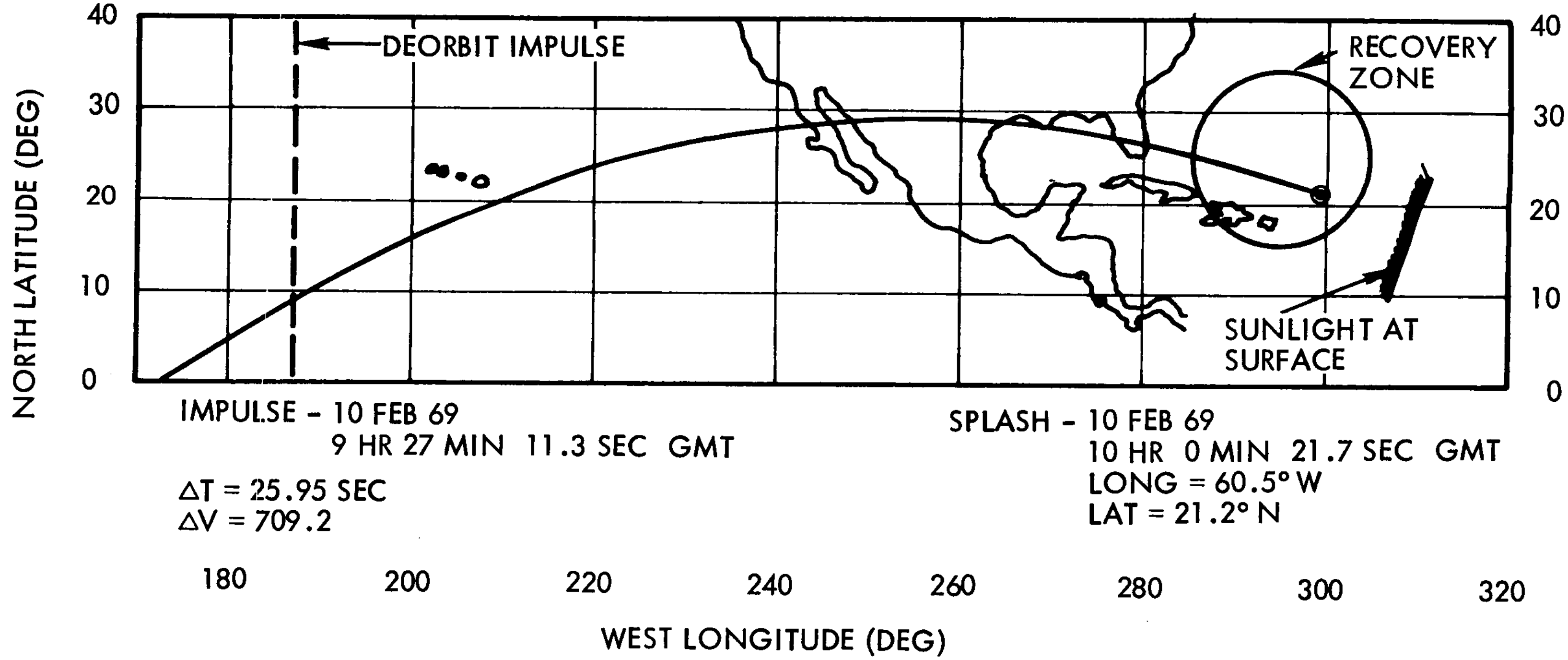


Figure 13. AAP-1 Ground Track During Deorbit Sequence

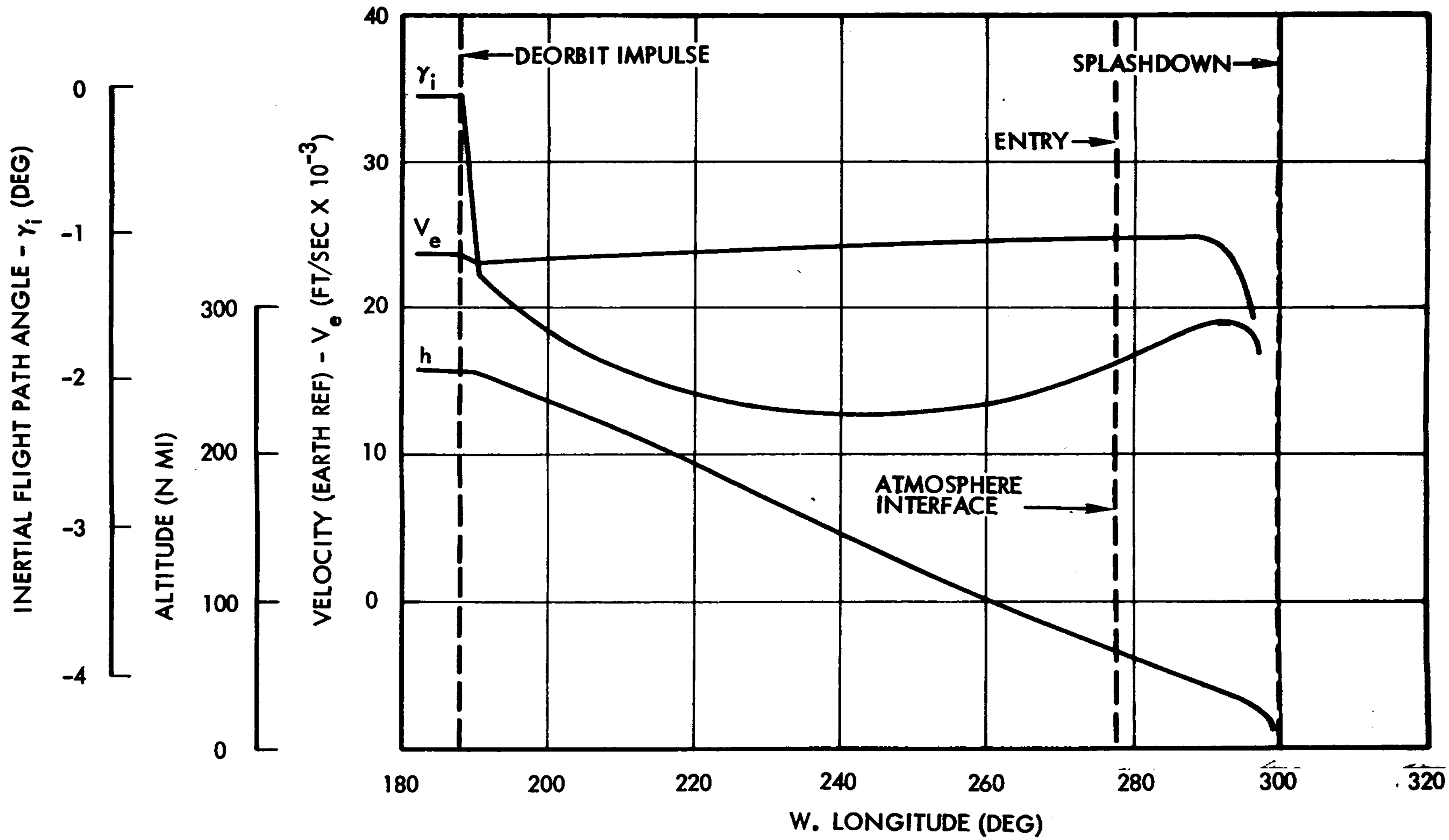


Figure 14. Flight Path Angle, Altitude and Velocity versus Longitude During Reentry

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